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Soil Survey of Iowa, Report No. 14—Black Hawk County

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SOIL SURVEY OF IOWA

BLACK HAWK COUNTY

AGRICULTURAL EXPERIMENT STATION
IOWA STATE COLLEGE OF AGRICULTURE
AND MECHANIC ARTS

Agronomy Section
Soils

Soil Survey Report No. 14
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SOIL SURVEY OF IOWA

Report No. 14---BLACK HAWK COUNTY

By W. H. Stevenson and P. E. Brown, with the assistance of G. E. Corson and H. J. Harper

An oat field on a characteristic Black Hawk county upland farm

IOWA AGRICULTURAL
EXPERIMENT STATION
C. F. Curtiss, Director
Ames, Iowa

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BLACK HAWK COUNTY SOILS*

By W. H. Stevenson and P. E. Brown, with the assistance of G. E. Corson and H. J. Harper

Black Hawk county is located in northeastern central Iowa, in the fourth tier of counties south of the Minnesota state line and in the fourth tier west of the Mississippi river. It is in the Iowan drift soil area and hence the major portion of its soils are glacial in origin. Much of the county has been covered by loess deposits, however, and the soils on a considerable area are mapped as loessial.

The total area of the county amounts to 565 square miles or 361,600 acres. Of this area, 328,745 acres, or 90.9 percent, is in farms. The total number of farms is 2,126 and the average size is 155.1 acres. The following figures taken from the Iowa Yearbook of Agriculture for 1917 show the utilization of the farmland of the county:

Acreage in general farm crops	209,280
Acreage in pasture	90,232
Acreage in orchards	904
Acreage in farm buildings, feed lots and public highways	14,507
Acreage in waste land	2,649
Acreage in crops not otherwise listed	2,002

The livestock industry is well developed in Black Hawk county and dairying is also of considerable importance. General farming is practiced to some extent, and there is some sale of corn and grain crops out of the county. In general the crops produced on most of the farms are used for feeding purposes and the chief income of the county is from the sale of stock. Trucking is practiced on a few areas near Waterloo and Cedar Falls, and potatoes, onions, cabbage and some other crops are grown very successfully. Sweet corn is produced on many farms around Waterloo, Cedar Falls and LaPorte City to supply the canneries. These crops are also grown in gardens on most farms to supply the home demand. Orchards are quite generally maintained, apples being the chief fruit grown. Cherries are also produced to some extent. The production of these fruits is used up on the home farms and on the local markets. The berries grown on small areas also serve to supply the homes and the local markets.

There is a relatively large area of waste land in the county and some of this might be utilized for crops if properly handled. General methods of treatment for such land cannot be suggested as the causes for lack of utilization are many and various. In the descriptions of individual soil types given later in this report the methods which may be used to reclaim waste areas are given, and advice along this line for special cases may be secured from the Soils Section of the Iowa Agricultural Experiment Station.

The general farm crops grown in Black Hawk county in the order of their importance are corn, oats, hay, potatoes, barley, rye, wheat and alfalfa. The acreage, yield and value of these crops in the county are given in table I.

*See Soil Survey of Black Hawk county by W. E. Tharp, of the U. S. Department of Agriculture, and H. J. Harper, of the Iowa Agricultural Experiment Station.

TABLE I. AVERAGE YIELDS AND VALUES OF THE GENERAL FARM CROPS GROWN IN BLACK HAWK COUNTY*

Crop	Acres	Percent of total farm land in the county	Bu. or tons per acre	Total bushels or tons	Average price	Total value of crop
Corn	109,000	33.15	39	4,251,000	.97	$4,123,470
Oats	57,500	17.50	53	3,047,500	.61	1,858,975
Spring wheat	230	.07	27	6,200	1.94	12,028
Winter wheat	400	.12	24	9,600	1.97	18,912
Barley	2,800	.85	32	89,600	1.15	103,040
Rye	1,150	.35	24	27,600	1.58	43,608
Potatoes	1,600	.45	112	179,200	1.32	236,544
Tame hay	29,000	8.82	1.4	40,600	18.82	764.092
Wild hay	7,500	2.28	1.1	8,200	14.79	121,278
Alfalfa	100	.03	2.0	200	23.40	4,680
Pasture	90,232	27.44	....	....	....	....

Corn is the most important crop in the county both in acreage and value. Over 33 percent of the total area of the county is devoted to this crop. The average yield of corn for the county is 39 bushels per acre. Practically all of the corn produced is fed in the county, probably not over 5 to 10 percent being shipped out. There are over 500 silos in the county and much of the corn is used for ensilage.

Oats is the second crop in acreage and value. Average yields of 53 bushels per acre are obtained. This crop is used in most rotations and while it is not considered a "money" crop, the profit from it is considerable, particularly when the yields are high, as is often the case in favorable seasons. A part of the oat crop is sold direct to the elevators but much of it is fed on the farms.

Tame hay is grown on a large area and it is a valuable crop. It consists mainly of timothy and clover but each of these crops is sometimes grown alone. Wild hay grows on many areas and the value of this crop is also considerable. Most of the hay crop, both tame and wild, produced in the county is used for feeding purposes but some is shipped out.

The production of potatoes is large and the value of the crop is considerable. Except for a few areas near Waterloo and Cedar Falls, however, they are not produced on a commercial scale. Practically all of the crop is utilized for home consumption or on the local markets. Average yields of this crop are 112 bushels per acre.

Barley is grown to some extent in the county and yields on the average 32 bushels per acre. Rye is produced on a small area and yields of 24 bushels per acre are secured. Wheat, both spring and winter varieties, is now grown on only a small acreage. This crop was formerly grown extensively in the county but repeated failures led to its decline in popularity and it is now of little importance. The winter varieties are preferred to the spring but the yields are extremely variable. The average recorded in the table shows 27 bushels for the spring wheat and 24 for the winter wheat. Alfalfa is grown only in a limited area but good yields are secured where the soil is properly prepared and seasonal conditions are normal. The alfalfa acreage is gradually increasing.

The character and extent of the livestock industry in Black Hawk county are shown in the following figures from the 1917 Iowa Yearbook of Agriculture:

*Iowa Yearbook of Agriculture, 1917.

Horses (all ages)	13,736
Mules (all ages)	233
Swine (on farms January 1, 1918)	81,250
Cattle (cows and heifers kept for milk)	16,668
Cattle (other cattle not kept for milk)	24,097
Cattle (total, all ages)	47,138
Sheep (all ages, on farms)	1,914
Sheep (total pounds wool clipped)	13,800

The raising of hogs is the most important livestock industry in the county and large numbers are marketed or slaughtered each year. Dairying is an important industry and there are many herds of Guernsey, Holstein and Jersey cattle. Near Waterloo and Cedar Falls there are a number of large dairy farms and dairy products are sold from many of the farms on which only a few dairy cattle are kept. There are several creameries scattered over the county and the income from dairying runs into the millions. The raising of cattle is practiced to some extent, but cattle feeding is not an important industry. The breeding of draft horses is practiced to some extent and sheep raising is also of some importance.

The value of land in Black Hawk county is quite variable, depending upon the character of the soil, the topography, the improvements and the location with reference to towns and to railroads. Well improved farms on the Tama silt loam sell for $250 and even more, per acre. The O'Neill soils bring at least $75 to $100 per acre and frequently much more than this. Even the first bottom soils which are utilized for pasture bring $50 to $100 per acre.

The soils of Black Hawk county are in general quite productive, in many cases without special methods of treatment being followed. In some areas, however, the natural fertility of the soils is not high and in many other cases the productive power of the soils has been reduced considerably and yields of crops are decreasing rather than increasing. It is quite essential that proper methods of soil management be adopted in all cases if the soils of the county are to be made satisfactorily productive and kept in a high state of fertility.

The need of lime is evidenced on practically all of the soil types in the county. In some instances the acidity is not great but in other cases the need of lime is pronounced. None of the soils show any considerable presence of lime or other bases and hence even in those few types where the reaction is now basic, the need for lime will be apparent in the near future. All the soils of the county should be tested for their reaction and lime applied as shown to be necessary. Only in this way can proper production of crops be insured, particularly of legumes.

Applications of farm manure have been shown to bring about large increases in crop production on practically all the soil types. This material should evidently be used as generally as possible and in as large amounts as production will permit. The organic matter content of many of the soils is low and in such cases farm manure should be used in particularly large amounts and if there is not enough of this material produced to supply the needs on all the soils of the farm, then green manures should be employed, preferably legumes. The latter are of great value in building up the sandy types to a higher crop-yielding power. Nitrogen may be supplied to the soil in the form of leguminous green manures and while the content of many of the types is not low, neither is it high and nitrogen must be added regularly if the supply is to be kept up. The phosphorus content of the soils of the county is quite low in many cases and in even the better soils it is not sufficient for any considerable period of heavy cropping. Phosphorus fertilizers are needed now on some of the types and they will be required on all in the future. Complete commercial fertilizers are probably less valuable on these soils than phosphorus carriers like acid phosphate or rock phosphate. The field experiments now under way will not permit of definite conclusions regarding these materials at the present time. Results covering several years must first be secured. Farmers should make tests on their own farms by applying these materials to small areas and thus learn definitely which fertilizer is profitable under the particular conditions.

The need of drainage is evident in some cases in different parts of the county and tile should be used wherever the fertility of the soil is reduced because of improper drainage. The rotation of crops is always necessary. The proper cultivation of the soil and the careful return of all crop residues such as straw and stover are other methods of soil treatment which are quite well-known and commonly practiced, and they are likewise quite necessary.

THE GEOLOGY OF BLACK HAWK COUNTY*

The rock formations underlying the soil of Black Hawk county are buried so deeply under deposits of drift or loess or both that there is no influence whatever upon the character of the soils and the geology of the county prior to glaciation is of practically no significance agriculturally.

At least twice during the glacial age great ice sheets swept across the county and upon their retreat, vast deposits of debris, known as glacial drift or till, were left behind. These deposits were composed of rock material gathered up by the glaciers during their movement down from the north and they are therefore extremely variable in composition and bear no relation to the underlying native rock formation in the county.

The first deposit, known as the Kansan, covered almost four-fifths of the county and was in turn covered by the Iowan. The actual depth of the Kansan drift is difficult to determine but where the total deposit is the deepest, the Kansan drift layer is about 240 feet in thickness. It varies from this depth to a few feet in the shallowest places. The basis of this drift is a blue clay mixed with many other materials such as quartz grains, pebbles, and larger masses of minerals. Pockets of sand and gravel and layers of these materials are common. When exposed at or near the surface, this till is oxidized to a yellow, brown or gray clay and its composition is changed, due to leaching. Deposits of gravel twenty or more feet in thickness are found in some places in the county. These beds were formed at the time of the deposition of the Kansan drift and they consist of fine gravel or coarse sand, yellow in color and rather uniform in texture. The largest deposit is along Dry Run, one-half mile directly east of the Iowa State Teachers' College. This material has been extensively used for ballast on the railroads and it is also of use for gravelling the roads.

The second great glacier left a deposit of drift upon its retreat which covered the preceding deposit almost entirely. This second layer of till is known

*Iowa Geologicay Survey. Vol. 16, 1905.

as the Iowan. It is nowhere as thick as the Kansan varying from a foot to five or seven feet in thickness where it is the deepest. On the tops of the ridges it is usually scarcely more than a foot thick while in the depressions between the ridges it is of course much thicker. This drift layer is a bluish-gray or drab clay where it has not been weathered but where it is exposed to oxidation, the color has changed to a brown or yellowish-brown. In texture it ranges from a heavy clay to a sandy or gravelly clay. Pockets of sand and gravel are occasionally found and glacial boulders of varying size and description are found over the surface and scattered thru the drift layer. The gravel and rock particles are usually more abundant in the subsoil than at the surface. Where this drift has been weathered to form soil, the latter is usually a fine loam, underlain by clay, sandy clay or clay loam. The lime which was originally present in the drift material has been largely leached away and the soils are now generally distinctly acid in reaction.

Some time after the most recent drift deposit, a layer of so-called loess was deposited by the wind over a large portion of the county. This loess covers practically all the county south and west of the Cedar river and about 32 percent of the soils of the county are derived from it.

There is considerable variation in the thickness of the loess layer. On the slopes to the Cedar river and Black Hawk creek, it is 25 to 30 inches in depth but there is a gradual deepening toward the southwest and in the extreme southwestern part of the county, it ranges from 40 to 50 inches in thickness.

Most of the loess material consists of silt and ranges in color from a dark-brown to a light-brown, depending upon the amount of organic matter which has accumulated since its deposition. There has been considerable leaching and the lime content has been quite generally removed, the loess types now showing an acid reaction in practically all cases. The soils formed from the loess are, however, quite fertile and seem to have retained a large portion of their valuable mineral constituents.

PHYSIOGRAPHY AND DRAINAGE

In topography, Black Hawk county presents the general appearance of a gently rolling prairie cut by the valleys of the Cedar and Wapsipinicon rivers and their tributary streams.

The upland areas, south and west of the Cedar valley, in general are gently rolling with some areas which are almost level. North and east of the Cedar there are broad rolling ridges which occasionally merge into broad level plains.

Low bluffs border the valley of the main fork of the Cedar river and of the Beaver creek on the south. These bluffs increase in height toward the east where they join the higher bluffs of the Cedar river. Above Cedar Falls the bluffs of the Cedar rise to an average height of sixty feet. South of Cedar Falls the slopes to the valleys are much less steep and there is a gradual rise from the valleys to the upland. West of the Cedar river and north of Waterloo there is little valley, the uplands bordering close upon the streams. On the opposite side of the river toward the east, there are wide sandy plains, somewhat uneven in topography, representing largely the old floor plains of the river. In this area there are many low sand ridges which extend in a northwest-southeast direction. Below Waterloo the valley is much narrower and

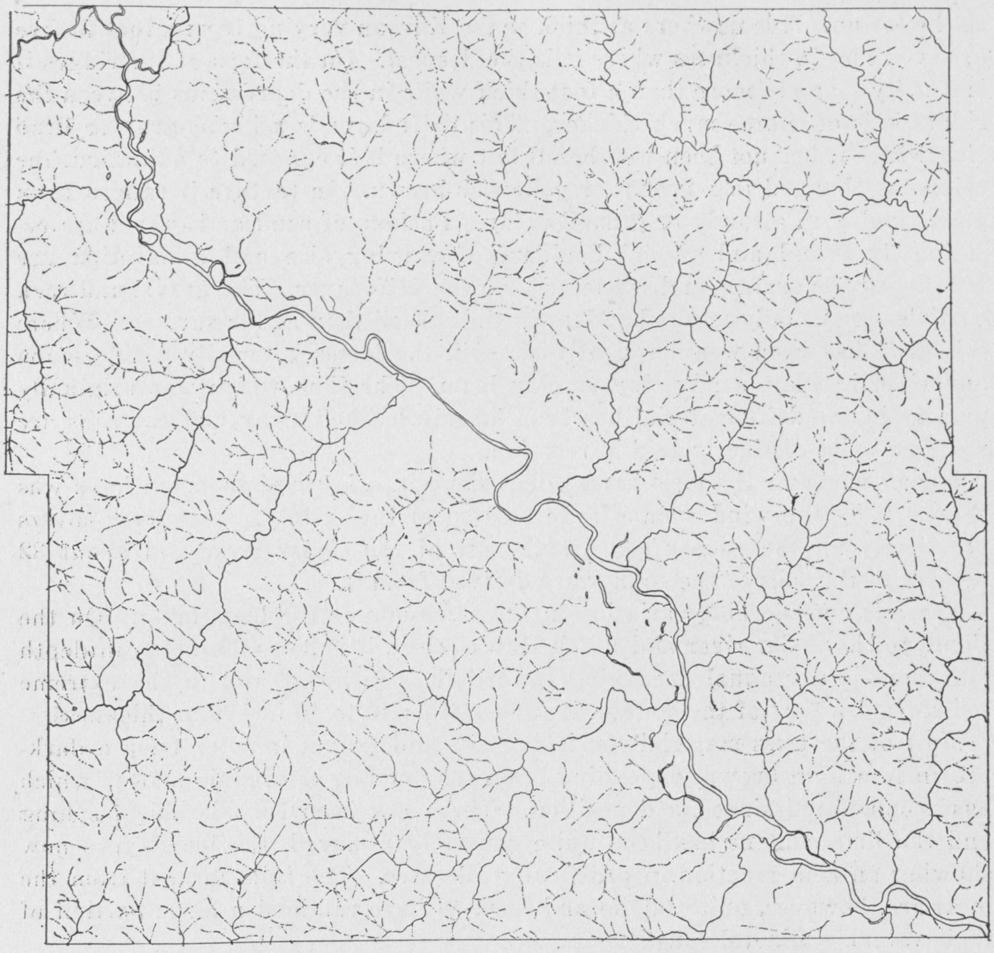


Fig. 1. Natural drainage system of Black Hawk county

these ridges of sand are absent. Extending south from Waterloo, the valley on the west consists mainly of terraces lying 10 to 20 feet above the flood plain of the river, while on the east the vallleys are narrow and there is little bottomland or terrace. The valley of Black Hawk creek in the southwestern part of the county is generally low and flat and rather narrow. Just south of Waterloo, however, the valley consists mainly of low terraces. Miller's creek in the south central part of the county has a narrow high terrace valley until it approaches the Cedar river, where the terraces become wide and low. Elk Run, a tributary of the Cedar on the east has a rather wide valley comprised mainly of high terraces.

The valley of the Wapsipinicon river in the northwestern part of the county is from one to three miles wide and the terraces, which occur chiefly on the western side, are low. Crain creek has a flat valley composed mostly of poorly drained bottomland. Spring creek in the southeastern part of the county has a narrow valley consisting mostly of terrace land.

The drainage of the county is accomplished almost wholly by the Cedar river and its numerous tributaries. This river extends diagonally across the county

SOIL MAP OF BLACKHAWK CO.

LEGEND

Drift Soils

- 1 Carrington loam
- 55 Webster loam
- 83 Carrington silt loam
- 3 Carrington sandy loam
- 4 Carrington fine sandy loam
- 119 Carrington sand
- 123 Thurston loamy sand
- 85 Clyde silty clay loam

Loess Soils

- 120 Tama silt loam
- 80 Clinton silt loam
- 121 Tama silt loam (rolling phase)
- 104 Dodgeville silt loam (shallow phase)
- 122 Clinton fine sandy loam

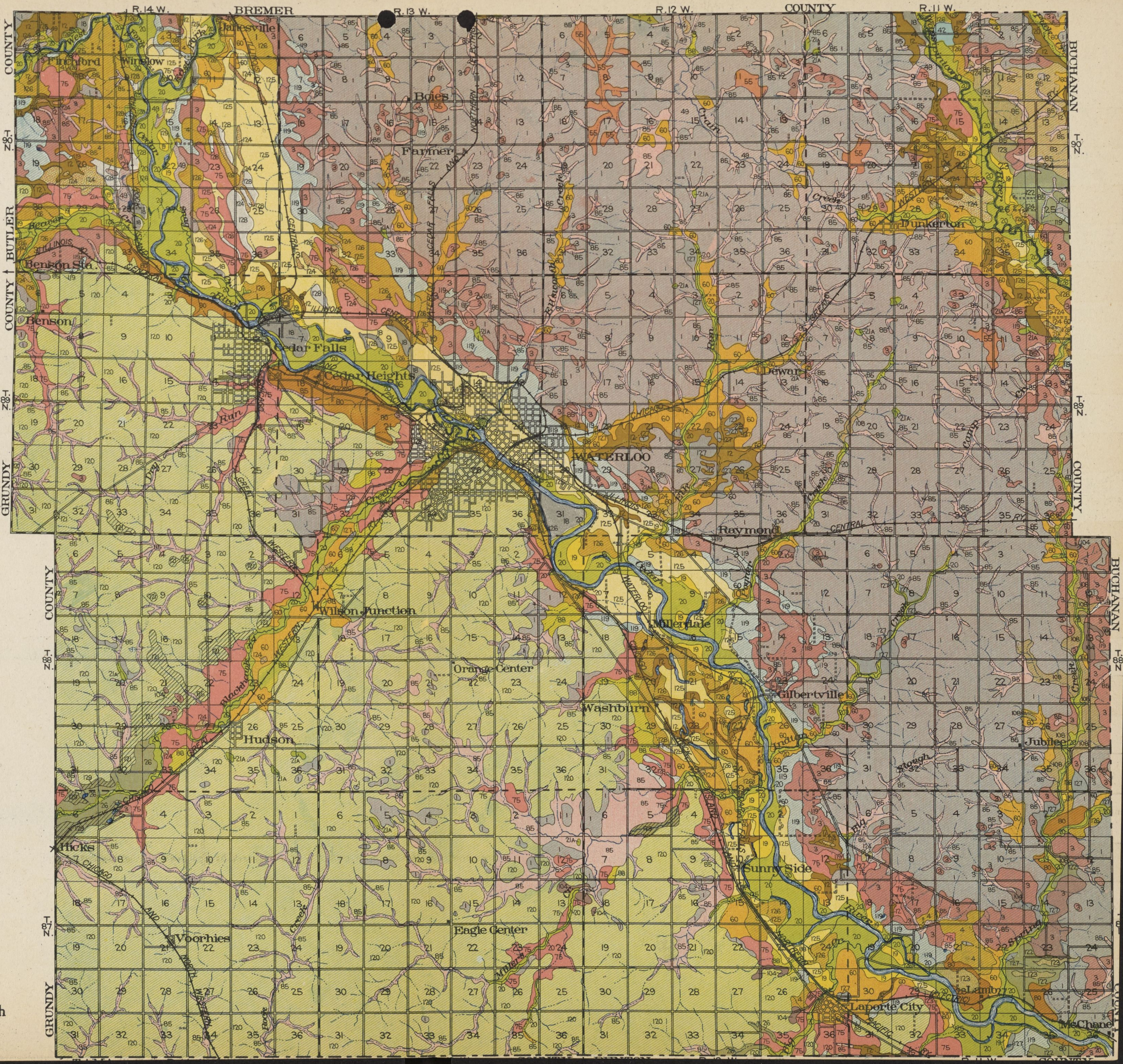
Terrace Soils

- 12 Bremer loam
- 88 Bremer silt loam
- 42 Calhoun silt loam
- 108 O'Neill loam
- 126 O'Neill sandy loam
- 125 O'Neill corse sandy loam
- 124 O'Neill sand
- 60 Waukesha loam
- 127 Waukesha sandy loam
- 128 Waukesha fine sandy loam
- 75 Waukesha silt loam

Swamp and Bottomland Soils

- 18 Cass loam
- 19 Cass sandy loam
- 49 Wabash loam
- 26 Wabash silt loam
- 128 Wabash silt loam (heavy phase)
- 21A Muck
- 20 Meadow

Scale: 1 Inch 2½ Miles.



MIDLAND MAP AND ENGINEERING CO.

from northwest to southeast. In the western part of the county, the chief tributaries are Beaver, Dry Run, Black Hawk, Millers, Big and Rock creeks. To the east, Elk, Indian and Spring creeks drain the larger area of that part of the county. The Wapsipinicon river cuts across the northeast corner of the county and with its chief tributary, Crain creek, it drains that part of the county.

The natural drainage system of the county is in general quite adequate and most of the upland is well drained. There are some areas, however, where drainage would be of value especially in the south central part of the county. The drainage system of the county is shown in the accompanying map.

THE SOILS OF BLACK HAWK COUNTY

There are four groups of soils in Black Hawk county, drift soils, loess soils, terrace soils and swamp and bottomland soils. They are placed in these groups on the basis of their origin and location.

Drift soils are those deposited by glaciers upon their retreat and they contain material from various sources and sometimes pebbles and boulders. Loess soils are fine, dust-like deposits made by the wind at some time when climatic conditions were very different than at present. Terrace soils are old bottomlands which have been raised above overflow by a decrease in the volume of the streams by which they were formed or by a deepening of the river channels. Swamp and bottomland soils are those occurring in low, poorly-drained areas or along streams, and are subject to more or less frequent overflow.

The total acreage and the percent of the area of the county included in each of these four groups of soils is shown in table II.

The largest area of the county, 44 percent, is covered by the drift soils. The loess soils are second in extent, covering 32.4 percent of the total area of the county. The terrace soils are much less extensive, covering only 15.9 percent of the county while the swamp and bottomland types are comparatively small in area, all together covering 7.7 percent of the county.

The loess and drift soils making up the upland of the county are usually gently rolling to almost level in topography. Some areas are somewhat rough but the proportion of land in the county which is too steep for cultivation is relatively small. The terrace soils are generally level in topography and many of them are very fertile, often yielding as well or even better than the uplands. The bottomland types are all level in topography and subject to overflow. Some of them are in need of drainage but more often their chief need is for protection from overflow.

Some of the upland types, as the Clyde silty clay loam, are also in need of drainage but in general the soils of the county are fairly well drained.

There are twenty-seven distinct soil types in Black Hawk county and these with two phases, the rolling phase of the Tama silt loam and the heavy phase

TABLE II. AREAS OF DIFFERENT GROUPS OF SOILS IN BLACK HAWK COUNTY

Soil groups	Acres	Percent of total area of county
Drift soils	159,744	44.0
Loess soils	117,184	32.4
Terrace soils	57,088	15.9
Swamp and bottomland soils	27,584	7.7
Total	361,600	....

TABLE III. AREAS OF DIFFERENT TYPES IN BLACK HAWK COUNTY

Soil No.	Soil type	Acres	Percent of total area of county
	DRIFT SOILS		
1	Carrington loam	103,859	28.7
85	Clyde silty clay loam	28,672	7.9
3	Carrington sandy loam	12,224	3.4
119	Carrington sand	7,936	2.2
4	Carrington fine sandy loam	3,136	0.8
83	Carrington silt loam	1,421	0.4
55	Webster loam	1,280	0.3
123	Thurston loamy sand	1,216	0.3
	LOESS SOILS		
120	Tama silt loam	110,336)	
121	Tama silt loam (rolling phase)	1,792)	31.0
80	Clinton silt loam	2,880	0.8
122	Clinton fine sandy loam	1,792	0.5
104	Dodgeville silt loam (shallow phase)	384	0.1
	TERRACE SOILS		
125	O'Neill coarse sandy loam	14,784	4.1
60	Waukesha loam	11,904	3.3
75	Waukesha silt loam	11,584	3.2
126	O'Neill sandy loam	6,528	1.8
12	Bremer loam	4,096	1.1
88	Bremer silt loam	2,176	0.6
124	O'Neill sand	2,112	0.6
108	O'Neill loam	1,472	0.4
127	Waukesha sandy loam	1,344	0.4
128	Waukesha fine sandy loam	960	0.3
42	Calhoun silt loam	128	0.1
	SWAMP AND BOTTOMLAND SOILS		
20	Meadow	19,136	5.3
49	Wabash loam	2,944	0.8
19	Cass sandy loam	2,176	0.6
26	Wabash silt loam	1,024)	
129	Wabash silt loam (heavy phase)	640)	.0.5
18	Cass loam	1,472	0.4
21a	Muck	192	0.1
	Total	361,600	....

of the Wabash silt loam and the areas of Meadow and Muck make a total of thirty-one separate soil areas. There are eight drift soils, five loess soils, eleven terrace types and seven swamp and bottomland soils. These various soils are distinguished on the basis of certain characteristics which are discussed in the appendix to this report, and the type names which are employed denote certain group characteristics. The areas of these soil types and the percent of the total area of the county covered by each type are shown in table III.

The drift soils are classed in the Carrington, Clyde, Webster and Thurston series. The Carrington loam is by far the most extensive type, covering 27.6 percent of the county. With the exception of the Tama silt loam, it is the largest type in the county. The Clyde silty clay loam is the second largest drift soil covering 7.9 percent of the county. It is the third largest type in the county. The Carrington sandy loam, Carrington sand and Carrington silt loam are the third, fourth and fifth drift types, covering 3.4, 2.2 and 1.5 percent of the county, respectively. The three remaining drift types are minor in extent, each covering less than one percent of the county. The loess soils belong in the

Tama, the Clinton and the Dodgeville series. The Tama silt loam is the largest individual soil type in the county, as well as the most extensive loess type. With the small area of the rolling phase, it covers 31 percent of the total area of the county. The other loess types are all minor in extent, each covering less than one percent of the county. The shallow phase Dodgeville silt loam is particularly unimportant.

The terrace soils are classed in the O'Neill, the Waukesha, the Bremer and the Calhoun series. None of the types is very extensive. The O'Neill coarse sandy loam is the largest, covering 4.1 percent of the total area of the county. The Waukesha loam and the Waukesha silt loam are about equal in area, the former covering 3.3 percent and the latter 3.2 percent of the county. The O'Neill sandy loam and the Bremer loam are much smaller in extent, covering 1.8 and 1.1 percent of the county, respectively. The remainder of the terrace types are small and rather unimportant, each one covering less than one percent of the county. The Calhoun silt loam is the smallest terrace type and it covers only 128 acres.

The bottomland soils belong in the Wabash and Cass series and there are areas of Meadow and Muck which cannot be classified into soil types. The variable material mapped as Meadow covers the largest area of bottomland and it is the fourth largest area in the county, covering 5.3 percent of the total area of the county. The other bottomland types are all minor in extent, none covering as much as one percent of the county. The area of Muck is particularly small and unimportant.

THE FERTILITY IN BLACK HAWK COUNTY SOILS

Samples were taken from all the soils in the county except the shallow phase Dodgeville silt loam and the Meadow, the former being very minor in extent and the latter so variable that an analysis would mean little. The more extensive types were sampled in triplicate and one sample only taken from the minor types. All the samples were taken with the utmost care, that they should represent accurately the typical soils and that variations due to local conditions or special treatments should be eliminated. Samplings were made in all cases to three depths, 0-6 2/3 inches, 6 2/3 -20 inches and 20-40 inches, representing the surface, subsurface and subsoils respectively. Analyses were made for total phosphorus, total nitrogen, total organic carbon, inorganic carbon and limestone requirement. The official methods were used for phosphorus, nitrogen and carbon and the Veitch method for limestone requirement.

The results given in the tables are the averages of duplicate determinations on all the samples of each type analyzed. If more than one sample was taken, the results are the averages of four or six determinations.

THE SURFACE SOILS

The results of the analyses of the surface soils are given in table IV. They are calculated on the basis of 2,000,000 pounds of surface soil per acre to a depth of 6 2-3 inches.

There is considerable variation in the phosphorus content of the soils of the county, the amounts present ranging from 904 pounds in the Carrington sandy

TABLE IV. PLANT FOOD IN BLACK HAWK COUNTY, IOWA, SOILS

Pounds per acre of two million pounds of surface soil (0 - 6 2-3")

Soil No.	Soil type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limest'n requirement
	DRIFT SOILS					
1	Carrington loam	1,317	3,561	43,568	0	3,503
85	Clyde silty clay loam	2,225	11,008	146,366	0	Basic
3	Carrington sandy loam	904	1,535	20,106	0	2,145
119	Carrington sand	956	534	6,660	0	1,072
4	Carrington fine sandy loam	1,105	2,754	34,480	0	2,318
83	Carrington silt loam	1,455	4,770	64,580	0	1,546
55	Webster loam	1,269	4,909	65,880	0	3,038
123	Thurston loamy sand	997	946	12,040	0	1,072
	LOESS SOILS					
120	Tama silt loam	1,273	4,878	58,953	0	6,083
121	Tama silt loam (rolling phase)	1,105	3,034	39,600	0	357
80	Clinton silt loam	1,158	1,786	21,820	0	357
122	Clinton fine sandy loam	1,206	589	5,160	0	1,787
	TERRACE SOILS					
125	O'Neill coarse sandy loam	1,425	1,614	23,690	0	3,217
60	Waukesha loam	1,239	3,794	45,286	0	4,409
75	Waukesha silt loam	1,130	3,896	50,946	0	4,170
126	O'Neill sandy loam	1,055	1,438	18,873	0	3,217
12	Bremer loam	1,967	5,764	81,680	0	5,362
88	Bremer silt loam	1,364	4,838	63,940	0	893
124	O'Neill sand	1,145	957	12,120	0	1,787
108	O'Neill loam	1,441	3,406	41,080	0	6,435
127	Waukesha sandy loam	1,132	2,456	30,300	0	4,004
128	Waukesha fine sandy loam	1,266	2,182	25,960	0	3,217
42	Calhoun silt loam	1,616	2,770	36,840	0	357
	SWAMP AND BOTTOMLAND SOILS					
49	Wabash loam	1,731	5,142	62,740	0	6,077
19	Cass sandy loam	1,603	3,434	38,632	368	Basic
26	Wabash silt loam	1,751	5,584	68,240	0	6,792
129	Wabash silt loam (hvy. phase)	1,522	8,246	103,350	0	357
18	Cass loam	1,623	4,758	48,940	0	Basic
21a	Muck	1,145	37,126	481,840	0	2,502

loam to 2,225 pounds in the Clyde silty clay loam. There is no apparent relation between the various groups of soils and the phosphorus supply. The average of the bottomland types is somewhat higher than that of the other groups, due probably very largely to the smaller removal of the element by crop growth, which has been less on these soils. The terrace types average a little better than the loess soils but the drift soils vary so widely that any comparison with the average of these types would not be warranted. There is apparently more of a distinct relation between the soil type and the phosphorus content, altho conclusions are sometimes difficult to reach owing to the occurrence of unusually high or low amounts. In general the sands, sandy loams and loamy sands are lower in phosphorus while the silty clay loams, silt loams and loams are higher. The Waukesha silt loam, however, is lower than the fine sandy loam of the same series while the O'Neill coarse sandy loam is higher than the sandy loam and quite as high as the loam. The Clinton silt loam is lower than some of the sandy types and there are other exceptions. In general it seems to be true that the heavier types of soil are better supplied with phosphorus than the sandier types but the variations in no cases are sufficiently great to warrant any great differences in the conclusions regarding the need of phosphorus.

While phosphorus is not actually lacking in many of the soil types in the county, that element will be needed in the future on all the soils if they are to be kept fertile. Furthermore it seems quite probable that phosphorus fertilizers would prove of value now in some cases and would bring about distinct increases in crop growth. Definite recommendations cannot be made regarding any of the soils until the field tests now under way have yielded definite results. The indications point very clearly, however, to the need and value of phosphorus fertilization. Tests on the farm are highly desirable and no large areas should be treated with any fertilizer material until it has been tested on a small scale and its value proven for the particular conditions.

There is a wide variation in the nitrogen content of the soils of the county just as there was in the case of phosphorus, but the differences in nitrogen are much greater. Thus the poorest type in nitrogen, the Carrington sand, shows a content of 534 pounds per acre, while the richest, the Clyde silty clay loam shows a content of 11,008 pounds. The Muck of course goes very much higher than this in nitrogen, as would be expected from the nature of the material. It can hardly be considered as a soil type, however,

There is little relation between the groups of soils and the nitrogen content, the bottomland soils averaging somewhat higher than the other groups, as might be expected. Again, as in the case of phosphorus, there seems to be some relation between the soil type and the nitrogen content, the heavier soils being much better supplied with the element than the sandy types, which are subject to greater losses by leaching.

There are exceptions to this rule, however, and in some cases as for example, the Carrington fine sandy loam, the Waukesha sandy loam and the Cass soils, the nitrogen supply is as high as in many of the heavier types.

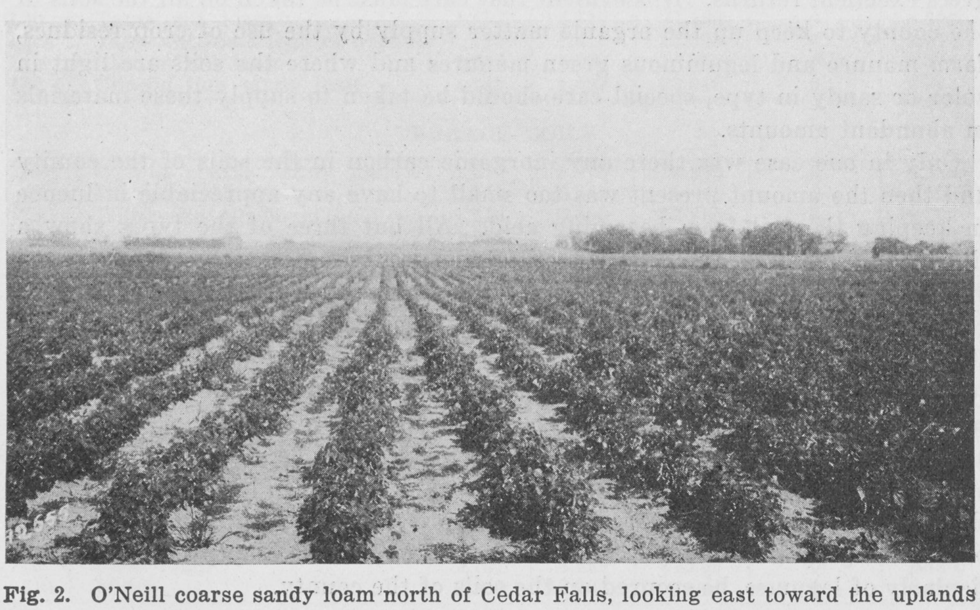


Fig. 2. O'Neill coarse sandy loam north of Cedar Falls, looking east toward the uplands

In general it appears that in most cases the nitrogen content of the soils of the county is not strikingly low. This does not mean, however, that the nitrogen supply in the soil may be considered inexhaustible. It will be reduced very rapidly if means are not employed to return that which is removed in the crops grown. Crop residues should all be returned, farm manure should be applied in as large amounts as the production of manure will permit and leguminous green manures must be used from time to time to supplement any lack of manure. If these treatments are followed the nitrogen supply may be kept at the best for crop growth and expensive nitrogenous fertilizers will not be needed. The legumes, when well inoculated, take considerable nitrogen from the air and thus increase the amount in the soil, when they are turned under for green manures. Such materials not only serve to keep up the nitrogen in the soil at a small expense but they also add much organic matter, which is likewise of value in keeping the soil in the best condition for crop growth. The organic carbon in the soil is a measure of the organic matter present and in general, it also indicates the nitrogen supply. Thus a high content of organic matter usually means considerable nitrogen and vice versa. There is usually a rather definite relation between the organic carbon and the nitrogen in soils.

The amount of organic matter in soils is indicated by the color of the soils. Thus the dark-colored types are generally richer in organic matter and nitrogen while light-colored soils are deficient in these constituents.

The organic carbon in the soils of Blackhawk county, with a few exceptions, is considerable, and the soils are dark in color. There is no relation apparent among the several groups of soil except that as in the case of nitrogen, the bottomland soils are somewhat higher in this constituent. The sandy types are generally lower while the heavier soils show a much higher content.

There is need for organic matter on these soils in some cases, however, and in fact even on the soils which are apparently fairly well supplied, manure gives excellent returns. It is evident that care must be taken on all the soils of the county to keep up the organic matter supply by the use of crop residues, farm manure and leguminous green manures and where the soils are light in color or sandy in type, special care should be taken to supply these materials in abundant amounts.

Only in one case was there any inorganic carbon in the soils of the county and then the amount present was too small to have any appreciable influence in keeping the soil from becoming acid. All but three of the types show a lime requirement by the Veitch method and in those three cases, there is no supply of lime present and the need for lime will soon be evidenced. The lime requirements shown in the table should be considered merely as indicative of the needs of the various soil types and in all cases individual soils should be tested. There is great variation in acidity in soils even among those of the same type and even average results such as are given should not be used in applying lime. By individual tests only can assurance be given that the exact amount of lime needed will be applied. Hence every soil in Black Hawk county should be tested at regular intervals for acidity and lime applied as shown to be necessary by the tests. In no other way can the best crop production, particularly of legumes, be secured on the soils of the county.

THE SUBSURFACE SOILS AND SUBSOILS

The results of the analyses of the subsurface soils and subsoils are given in Tables V and VI. They are calculated on the basis of four million pounds of subsurface soil and six million pounds of subsoil.

There is very little influence of plant food in the lower soil layers upon the fertility of the soil unless the amount is large. It is evident that there is no great supply of any constituent present in the subsurface soils and subsoils in Black Hawk county. It will not be necessary therefore, to consider these results in detail. The needs of the soils as shown by the analyses of the surface soils are borne out and emphasized by the analyses of the lower layers. Thus it is evident that the phosphorus supply is not large and phosphorus fertilizers will be needed now or in the near future. The organic matter supply and nitrogen content, while not extremely low, shows that these constituents will be required if the supply is to be kept up. There is no supply of lime in the lower soil

TABLE V. PLANT FOOD IN BLACK HAWK COUNTY, IOWA, SOILS

Pounds per acre of four million pounds of subsurface soil (6 2-3"-20")

Soil No.	Soil type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limest'n requirement
	DRIFT SOILS					
1	Carrington loam	1,804	3,904	51,306	0	6,577
85	Clyde silty clay loam	2,007	7,114	107,640	0	Basic
3	Carrington sandy loam	1,347	2,098	27,266	0	2,383
119	Carrington sand	1,307	1,409	14,840	0	1,430
4	Carrington fine sandy loam	1,364	2,002	25,320	0	2,318
83	Carrington silt loam	1,926	5,616	75,200	0	3,092
55	Webster loam	1,684	5,906	77,940	0	5,362
123	Thurston loamy sand	1,088	1,288	12,000	0	714
	LOESS SOILS					
120	Tama silt loam	1,657	6,110	71,160	0	8,392
121	Tama silt loam (rolling phase)	916	1,915	20,320	0	3,574
80	Clinton silt loam	2,000	1,622	16,680	0	714
122	Clinton fine sandy loam	1,138	1,622	20,040	0	3,864
	TERRACE SOILS					
125	O'Neill coarse sandy loam	1,670	2,275	26,980	0	4,289
60	Waukesha loam	2,416	5,466	68,000	0	6,596
75	Waukesha silt loam	1,616	5,400	63,800	0	9,752
126	O'Neill sandy loam	1,912	2,763	32,706	0	3,097
12	Bremer loam	1,791	5,264	63,920	0	12,870
88	Bremer silt loam	1,831	8,050	113,520	0	1,430
124	O'Neill sand	1,172	1,496	16,800	0	5,004
108	O'Neill loam	1,164	3,272	37,360	0	3,574
127	Waukesha sandy loam	1,266	2,484	29,360	0	9,608
128	Waukesha fine sandy loam	1,818	3,396	42,360	0	3,574
42	Calhoun silt loam	1,445	2,824	26,280	0	714
	SWAMP AND BOTTOMLAND SOILS					
49	Wabash loam	1,912	4,572	58,760	0	12,154
19	Cass sandy loam	2,586	7,376	75,240	0	Basic
26	Wabash silt loam	2,478	8,152	104,280	0	12,154
129	Wabash silt loam (hvy. phase)	3,044	9,408	130,080	0	714
18	Cass loam	1,751	4,232	47,520	0	Basic
21a	Muck	2,200	82,664	1127,040	0	6,434

TABLE VI. PLANT FOOD IN BLACK HAWK COUNTY, IOWA, SOILS

Pounds per acre of six million pounds of subsoil (20"-40")

Soil No.	Soil type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limest'n requirement
	DRIFT SOILS					
1	Carrington loam	1,818	2,717	34,455	0	8,311
85	Clyde silty clay loam	1,858	3,994	82,360	0	Basic
3	Carrington sandy loam	1,164	1,810	23,680	0	5,891
119	Carrington sand	1,919	1,224	13,620	0	Basic
4	Carrington fine sandy loam	1,738	1,686	14,760	0	3,216
83	Carrington silt loam	2,242	2,790	38,340	0	5,361
55	Webster loam	2,000	2,385	28,980	0	Basic
123	Thurston loamy sand	1,394	1,170	10,260	0	1,071
	LOESS SOILS					
120	Tama silt loam	1,959	3,630	48,660	0	6,076
121	Tama silt loam (rolling phase)	1,344	2,163	34,140	0	8,580
80	Clinton silt loam	1,515	990	14,040	0	3,477
122	Clinton fine sandy loam	2,895	6,678	91,980	0	5,361
	TERRACE SOILS					
125	O'Neill coarse sandy loam	2,526	1,296	17,820	0	3,391
60	Waukesha loam	2,409	3,499	44,660	0	10,666
75	Waukesha silt loam	2,112	3,654	41,860	0	10,009
126	O'Neill sandy loam	2,303	2,407	31,384	0	3,275
12	Bremer loam	1,919	1,884	27,900	0	5,361
88	Bremer silt loam	1,576	6,783	97,420	0	2,680
124	O'Neill sand	1,535	1,038	21,600	0	9,651
108	O'Neill loam	1,833	2,410	23,640	0	5,361
127	Waukesha sandy loam	1,313	1,933	22,740	0	7,506
128	Waukesha fine sandy loam	2,243	3,004	33,660	0	5,361
42	Calhoun silt loam	1,778	2,014	17,040	0	7,506
	SWAMP AND BOTTOMLAND SOILS					
49	Wabash loam	2,343	3,288	35,580	0	9,651
19	Cass sandy loam	1,879	1,170	18,798	0	Basic
26	Wabash silt loam	2,818	6,084	69,480	0	9,651
129	Wabash silt loam(hvy. phase	3,273	5,076	82,440	0	1,071
18	Cass loam	1,621	796	15,480	0	Basic
21a	Muck	3,186	81,420	1170,120	0	9,651

layers and while in a few cases the subsoils are basic in reaction, lime will be needed on all the soils not only at the present time but also at regular intervals in the future if the soils are not to become acid. Enough should be applied to neutralize the acidity of the surface soils and then two tons additional supplied. At regular intervals, such as once in a four year rotation, the soil should be tested and more lime added as needed. In this way the reaction of the soil may be made and kept basic, which is the best reaction for crop growth.

GREENHOUSE EXPERIMENTS

To gain some information regarding the needs of the soils of Black Hawk county and the possible value from the use of various fertilizing materials, three experiments were carried out in the greenhouse, one with the Tama silt loam, one with the Carrington silt loam and one with the O'Neill sandy loam. A fourth experiment on the Carrington loam from Bremer county is also included here as that type is extensive in Black Hawk county and it is identical with that occurring in Bremer county. The results are therefore directly

TABLE VII. GREENHOUSE EXPERIMENT

Tama silt loam—Black Hawk county

Pot No.	Treatment	Weight wheat grain in grams	Weight clover in grams
1	Check	12.00	8.0
2	Manure	12.65	31.0
3	Manure+Lime	12.86	51.5
4	Manure+Lime+Rock phosphate	14.03	57.0
5	Manure+Lime+Acid phosphate	12.72	64.5
6	Manure+Lime+Commercial fertilizer	13.67	59.5

applicable to Black Hawk county. It should be understood that greenhouse experiments are indicative only of what may occur in the field but they give valuable information in many cases regarding the needs of field soils. Field tests are now under way to check these greenhouse results and it will be shown later what agreement there is.

The first three tests were arranged identically, the same treatments being employed. Thus manure was added at the rate of 8 tons per acre, lime in sufficient amount to neutralize the acidity of the soil and two tons additional, rock phosphate at the rate of 2,000 pounds per acre, acid phosphate at the rate of 200 pounds per acre and a complete commercial fertilizer, a standard 2-8-2 brand, at the rate of 300 pounds per acre. Wheat and clover were grown in all cases, the clover being seeded about one month after the wheat was up.

The average results obtained from the duplicate pots on the Tama silt loam are given in table VII. It is evident that the application of manure had little effect on the wheat but the clover crop was increased enormously. Lime also showed little effect on the wheat but gave a large increase in clover. This might be expected since clover and other legumes are much more sensitive to acidity than the grain crops. Rock phosphate with manure and lime increased the wheat yield and it also brought about some increase in clover. Acid phosphate and the commercial fertilizer, on the other hand, when used with manure and lime had little effect on the wheat, the commercial fertilizer showing only a slight gain and the acid phosphate none at all. Both of these materials, however, gave a considerable effect on the clover, the acid phosphate showing up especially well, and both showed a greater effect on the clover than did the rock phosphate. On this soil type it appears that manure and lime should be used and that a phosphate fertilizer would probably give profitable returns. No conclusion concerning the relative merits of the rock and acid phosphate should be drawn.

In table VIII are given the average results from the duplicate tests on the Carrington silt loam.

TABLE VIII. GREENHOUSE EXPERIMENT

Carrington silt loam—Black Hawk county

Pot No.	Treatment	Weight wheat grain in grams	Weight clover in grams
1	Check	12.53	4.5
2	Manure	14.76	15.5
3	Manure+Lime	14.67	22.5
4	Manure+Lime+Rock Phosphate	13.93	21.0
5	Manure+Lime+Acid phosphate	15.22	28.5
6	Manure+Lime+Commercial fertilizer	16.75	36.5

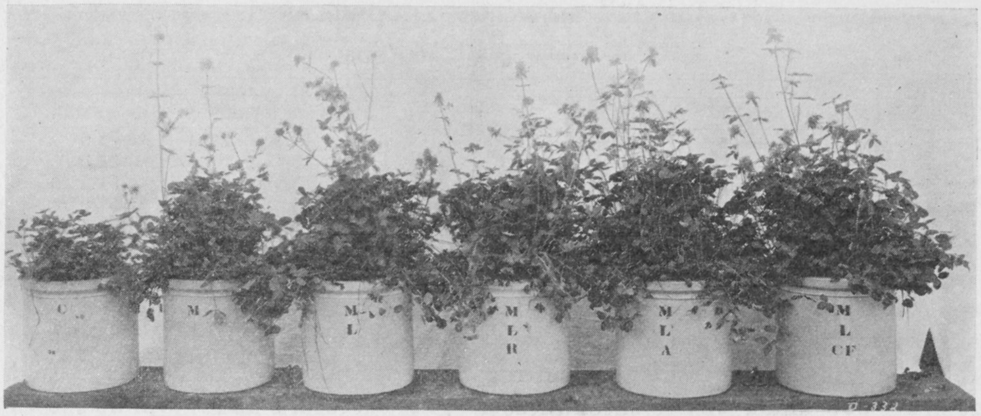


Fig. 3. Clover pot culture on Tama silt loam

On this type also the beneficial influence of manure is shown both on the wheat and on the clover. Lime gave an increase in clover but showed no effect on wheat. Rock phosphate applied with manure and lime had no effect on either wheat or clover. Acid phosphate, however, used with manure and lime brought about a decided increase in both crops, the effect being particularly evident in the case of the clover. The complete commercial fertilizer used with manure and lime gave a greater influence on both wheat and clover than did the acid phosphate. The increase from the use of this material was very pronounced in the case of the clover.

Again, as in the former case, this soil type seems to respond decidedly to

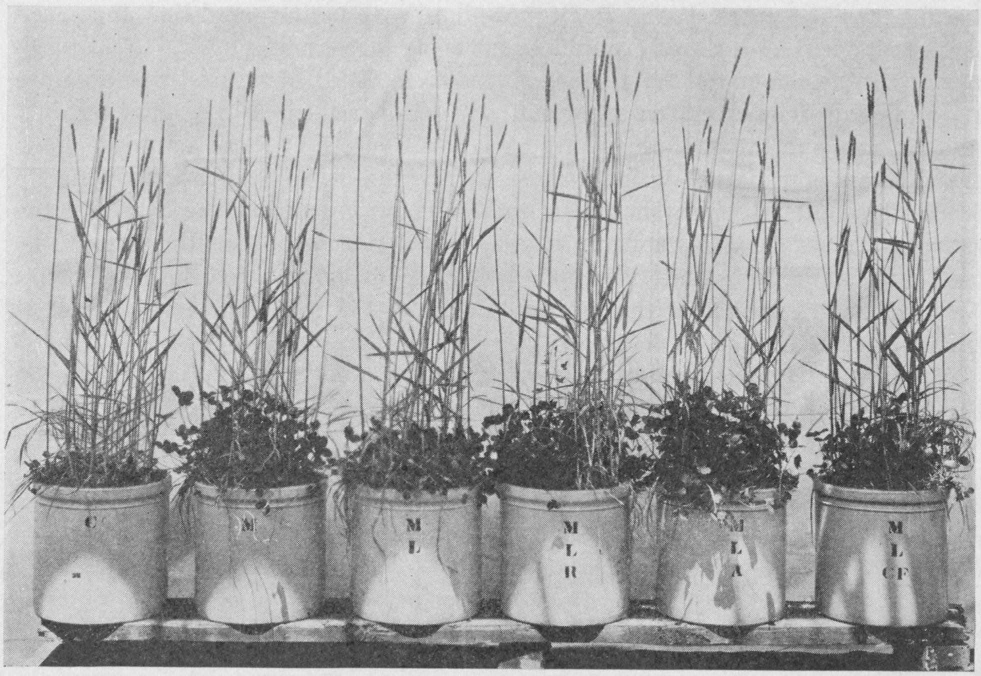


Fig. 4. Wheat and clover on Tama silt loam

Fig. 5. Clover pot culture on Carrington silt loam

applications of manure, lime and phosphorus. The treatments in all cases show up especially well on the clover but distinct increases in wheat are also shown. Only in the case of rock phosphate was no effect evidenced. From the fact that acid phosphate gave returns, however, it is evident that phosphorus is needed in this soil and possibly in field tests the rock will prove as good as the acid. No conclusions regarding the relative merits of these materials are permissible from these results. The evidence of superior value from the complete commercial fertilizer should also be checked by field tests and calculated on an economic basis before such a fertilizing material is chosen and used on a large scale.

The average results from the duplicate pots of the O'Neill sandy loam are given in table IX.

The manure showed an increase in the wheat crop and also in the clover. Lime apparently had little effect. The differences, however, are small and it should not be concluded that lime will not be needed on this type when acid. Field experience has demonstrated very definitely that lime should be used when the soil is acid, especially for clover, and increases are quite generally secured from its use in the field. Rock phosphate applied with manure and lime gave a distinct increase on the wheat crop but no effect on the clover. Acid phosphate showed no influence on either crop. The complete commercial fertilizer gave a considerable gain in wheat but it, too, showed no effect on the clover. Just why these materials should influence the wheat and not the clover is difficult to explain and it is difficult also to conclude why the acid phosphate had no effect. The results may have been influenced by some condition peculiar to the greenhouse. The results as a whole show quite definitely that manure, lime and phosphorus should be used on this soil to bring about

TABLE IX. GREENHOUSE EXPERIMENT

O'Neill sandy loam—Black Hawk county

Pot No.	Treatment	Weight wheat grain in grams	Weight clover in grams
1	Check	8.01	69.0
2	Manure	8.38	76.0
3	Manure+Lime	8.70	74.5
4	Manure+Lime+Rock phosphate	10.94	74.0
5	Manure+Lime+Acid phosphate	8.48	74.0
6	Manure+Lime+Commercial fertilizer	11.41	73.5

TABLE X. GREENHOUSE EXPERIMENT

Carrington loam—Bremer county

Pot No.	Treatment	Wt. wheat grain in grams
1	Check	8.25
2	Lime	9.25
3	Lime+Acid phosphate	11.25
4	Lime+Rock phosphate	9.50
5	Lime+Manure	19.00
6	Lime+Manure+Acid phosphate	18.75
7	Lime+Manure+Rock phosphate	20.50

increases in crop growth. The form in which the phosphorus should be applied must be determined by field tests but the distinct gain from the use of the rock phosphate surely indicates that phosphorus may be applied with profit on this soil type.

In the fourth greenhouse test a sample of Carrington loam from Bremer county was used and the treatments were somewhat different. Lime was added as in the other tests, manure was applied at the rate of 10 tons per acre, acid phosphate at the rate of 300 pounds and rock phosphate at the rate of 1,000 pounds per acre. The results of this test are given in table X, the figures being the averages of the yields of wheat on duplicate pots.

The addition of lime increased the yield of wheat to a noticeable extent and acid phosphate in addition to the lime gave a further distinct gain in crop. Rock phosphate, however, exerted but little effect. Manure used with lime doubled the yield and rock phosphate added with the manure and lime gave a further increase which was small. In this case, however, that is, with manure,

Fig. 6. Wheat on Carrington silt loam

Fig. 7. Clover pot culture on O'Neill sandy loam

the acid phosphate showed no effect. These results show very clearly the beneficial effects from the use of manure and lime on this soil and there are indications that phosphorus may be of value also.

These greenhouse experiments as a whole indicate that the needs of the main soil types in Blackhawk county are for manure, lime and in many cases phosphorus also. Farm manure seems to be particularly valuable and if this material cannot be applied in sufficient amounts, probably green manures should be used. Lime shows value, especially on legumes, and phosphorus fertilizers may be of use now and certainly will be needed in the future. The kind of phosphorus fertilizer to be used must be determined by special tests as it is impos-

Fig. 8. Wheat on O'Neill sandy loam

sible at the present time to choose between the two principal materials which are available for use.

THE NEEDS OF BLACK HAWK COUNTY SOILS AS INDICATED BY LABORATORY AND GREENHOUSE TESTS

The field tests now under way in Black Hawk county include the use of manure, crop residues, lime, rock phosphate, acid phosphate and a complete commercial fertilizer. These tests are located on different soils which are being farmed according to the livestock or the grain system.

Results from these field experiments have not yet been secured over a long enough period of time to warrant conclusions and they will be pulbished at a later date in a supplementary report. For the present it can merely be said that the results are showing the value of manure and lime and also giving indications that phosphorus fertilizers may prove profitable. The exact plan of these field tests is given in circular No. 51 of the Iowa Agricultural Experiment Station. The treatments recommended for the soils of the county are based at the present time upon the analyses, the greenhouse tests and on the experience of many farmers. No suggestions are made which have not proven of distinct value in the field by practical experience.

LIMING

With the exception of the Clyde silty clay loam and the Cass loam and sandy loam, the soil types in Black Hawk county all showed a need for lime, which in many cases was considerable. In no case was any appreciable occurrence of carbonates noted in the surface, subsurface or subsoils of any of the soils, even in those whose reaction was not acid according to the tests. This indicates that lime will be needed on all the soils in the near future even if it may not be necessary in individual cases now. All crops require a basic reaction in soil for their best growth and especially is this true in the case of legumes. In fact with the latter crops, the presence of lime may be the factor determining whether or not a profitable crop will be secured. When soils become acid, therefore, lime should be applied if the best crop growth is to be secured. Even if a distinctly acid condition is not found in a soil and there is no lime content, lime will soon be needed and tests should be made at regular intervals, or acidity will develop to a harmful extent. Lime and other bases are gradually lost from soils under cultivation, both by leaching and by reacting with acids which are being produced constantly. After lime has been applied to a soil, therefore, a few years of cultivation will lead to a need for a further application.

All the soils of Black Hawk county should be tested for acidity and lime requirement and the amount of lime shown to be needed according to the test should be applied. Farmers may test their own soils for acidity but it will generally be much more satisfactory for them to send a small sample to the Soils Section of the Agricultural Experiment Station and have it tested more accurately free of charge. By this means they may be certain that they are applying the exact amount of lime needed and not an excessive or an insufficient amount, both of which would be highly undesirable. The figures given in the tables earlier in this report are merely indications of the lime requirements and applications should not be made on the basis of these figures. The acidity in soils and the need of lime is one of the most variable factors connected with soils and wide variations often occur in samples from the same type even under what are supposed to be very similar conditions. The safest plan is to test the soil in every field and then the proper application of lime can be ascertained.

After the acidity of the soil has been neutralized, further need for lime may be evidenced in the course of a few years. It is generally desirable to test soils at least once in a rotation of three or four years and be certain that lime is present in sufficient amounts to insure the best growth of the legume in the rotation. The application should preferably be made just prior to the growing of the legume as for example, in the regular four year rotation, the application is made before the oats are seeded, discing the material in.

It is not feasible to apply sufficient lime to neutralize the acidity in the soil to a depth of forty inches but recommendations are based on application to the surface soil. Lime generally moves down in the soil and there will be a constant neutralization of the acidity in the lower soil layers. This is a further reason why the reaction of the surface soil should be constantly tested and lime applied at regular intervals.

The greenhouse experiments very largely confirmed the results of the analyses, showing a decided gain in crop growth, especially of the clover, where lime was applied to the Tama silt loam, the Carrington silt loam and the Carrington loam. Farm experience further confirms these results by showing large benefits from the use of lime. The field experiments now under way in the county have also shown already that lime must be used if the best yields are to be secured.

It is safe to say that one of the first needs of the soils of the county is for the testing of the soils and the use of lime in amounts shown to be necessary. Applications of this material will prove profitable and without it all other treatments will be less effective or even absolutely, without any beneficial influence.

Further information regarding the losses of lime from soils, the reasons for the value of lime, time of application, cost of material and other points connected with liming is given in Bulletin 151 and Circular 58 of the Iowa Agricultural Experiment Station.

MANURING

The soils of Black Hawk county in general are not strikingly deficient in organic matter, particularly in the case of the upland and bottomland types, but there are some soils which are very deficient in this material. Particularly is this true of the soils of the O'Neill series found on the second bottoms or terraces. There are also some sandy soils on the upland that are decidedly lacking in humus. In general it seems to be true that the more sandy types on the uplands and terraces are especially in need of applications of organic matter.

It is evident from the greenhouse tests that manure will be of value, however, not only on such sandy soils whose low humus content is apparent in the field, but also on such types as the Tama and the Carrington silt loam and the Carrington loam, which do not seem to be lacking in humus. Practical experience on the farm confirms this conclusion for it is quite generally found that manure brings about striking increases in crop yields and without manure other fertilizing constituents are of little value. The field tests in the county have already shown the value of manure and large applications may be made with the assurance of profit. There is no particular danger of applying too much manure as the amount produced on any farm is rarely sufficient to permit of an application of more than 8 to 10 tons per acre once in the rotation. More than this could probably be applied with profit but it is not considered advisable to apply more than 16 to 20 tons per acre because beyond these amounts the returns secured will not warrant the application.

The beneficial influence of manure on soils is due very largely to its effect on the physical condition of the soil. It opens up heavy clay soils and permits of better moisture and air conditions, it tightens up loose sandy soils and permits them to retain moisture and plant food. Manure also adds considerable plant food to the soil and the nitrogen, phosphorus and potassium which it contains may be of considerable value in lengthening the "life" of the soil. The chemical effects of manure are also of considerable significance. Then when the enormous numbers of bacteria in manure are introduced into the soil there is an immediate increase in the decomposition processes and in the production of available plant food, not only from the manure, but from the soil itself.

The beneficial effects of manure may be due in some cases to these bacteriological changes entirely; in some cases they may be due to the chemical effects and in other cases they may be due to the physical influence on the soil, but in general they are undoubtedly the result of all three working together.

The increases in crop growth brought about by the use of manure will be much reduced if the manure is not properly stored and applied to the soil. If it is exposed to the air and rain and the soluble portion is allowed to leach away, manure may lose 95 percent of its value in extreme cases and will generally lose about three-fourths of its value. When properly stored, moist and compact and under cover or when applied to the soil as produced, manure may return three-fourths or more of the plant food constituents contained in the crops used for feed. Thus not only will the greatest effect on crop growth be secured by using every care to prevent losses from manure but also the "life" of the soil will be lengthened and permanent fertility will be more readily and economically accomplished.

Even if all the manure produced on the average farm is stored carefully and applied to the soil, it will be insufficient on many livestock farms to keep the soils fertile or to supply the entire farm. On the grain farm where the production of manure is small, some other means must be employed to keep up the supply of organic matter. This can be accomplished by the use of leguminous green manures. Legumes can be grown in almost any rotation and turned under and when they are inoculated, as they always should be, nitrogen will be taken from the air and there will be a double effect from the organic matter added and from the increase in nitrogen in the soil. Non-legumes may be used as green manures but they do not add nitrogen and hence their value is generally less. Many of the soils in Black Hawk county might be benefited considerably by the use of leguminous green manures, especially in the case of the sandy, droughty soils which are subject to a loss of too much water and to a lack of nitrogen also. Green manures may be used in many cases as substitutes for or supplements to farm manure and their use may be distinctly profitable. Like many other practices, however, green manuring cannot be followed blindly nor carelessly nor can it be expected to prove of value if other soil conditions are not satisfactory. Advice regarding the use of green manures will be given by the Soils Section upon request.

The use of crop residues, straw and stover is a third means by which the organic matter content of the soil may be increased. Too often these materials are considered worthless and are burned or otherwise destroyed. They are of considerable value on the soil because of the organic matter which they contain and also because of the plant food which they actually return to the soil. In livestock farming, such materials should be used for feed or bedding and returned to the soil in the manure. Thus the greatest beneficial effect is secured as their decomposition is increased by the mixing with manure. On the grain farm they may be applied directly to the soil or allowed to decompose partly before application but they should be returned just as carefully as on the livestock farm. Indeed there is greater need for their return as the manure production is small and greater difficulty is experienced in keeping up the organic matter content of the soil. In short, crop residues, straw and stover are valuable natural means of keeping up the humus content of soils and they should never be burned or wasted.

THE USE OF COMMERCIAL FERTILIZERS

The phosphorus content of practically all the soils of Black Hawk county is low and it is evident that phosphorus fertilizers will be needed in the future even if they are not of great value at the present time. The greenhouse tests indicated some value from phosphatic fertilizers on the various soil types and field experiments indicate that they may be applied with profit to some soils altho results are not yet very definite and it can merely be said that phosphorus fertilizers may prove of value now in many cases, and they will certainly be needed in the future. The only way to determine whether or not phosphorus applications will prove profitable is to carry out a test on a small area. If the results are good, applications may then be made to larger areas with the assurance of profit. Farmers may carry out such tests on their own soils and thus solve the problem for their own conditions. Specific directions for such tests are given in Circular 51 of the Iowa Agricultural Experiment Station and advice may be secured for special tests, from the Soils Section.

The results thus far secured do not permit of a choice being made between acid phosphate and rock phosphate. Eventually it is hoped that the field experiments will yield definite results along this line. For the present it can merely be urged that farmers test the two materials and determine which is the most profitable. It is quite desirable to use not only the cheapest but also the most profitable fertilizing material. Rock phosphate is the cheaper form of phosphorus but it is not so readily available and the acid phosphate may be more valuable even if it costs more. Tests of the two materials may readily be made on the farm and the most desirable form chosen for application to large areas.

Nitrogen is present in most of the soils of the county in considerable amounts but the supply is not inexhaustible and in many cases the amounts present are so low that nitrogen may soon become a controlling factor of growth. It will not be necessary to use commercial nitrogenous fertilizers on these soils, however, provided leguminous crops are used as green manures. Inoculated legumes are the cheapest and best means of adding nitrogen to the soil and as has been pointed out, they may be used as green manures in almost any rotation. The nitrogen supply in the soil may thus be kept up by using the inexhaustible supply in the atmosphere for the growth of these legumes and fixing the nitrogen in the soil, where it can be used by non-leguminous crops in the rotation. The soils of Black Hawk county might be benefited in some cases now by the addition of nitrogen in this way and in general it must be emphasized that leguminous green manures must be used to keep up the supply of nitrogen. Only in small applications as top dressings can commercial nitrogenous materials probably be used with profit. If they are tested, however, and give profitable crop increases, there is no objection to employing them.

Potassium has been shown* to be present in nearly all the soils of the state in such large amounts that it is not considered that potassium fertilizers would prove profitable. If the soils are kept in the best physical condition for bacterial action, there will be a very rapid production of available potassium and the crops will be kept supplied. If the proper physical conditions for such desirable action are not observed the crop will not be satisfactory for other reasons, as well as because of lack of available potassium. The soils of Black Hawk county in general probably will not respond profitably to application of potassium fertilizers but if tests show a profit, the materials may be used. Some potassium salts were used at one time in the county and increases in crops were reported. No records were kept, nor was the profit determined, so that little evidence of value was secured. On soils rich in organic matter, newly drained, and cropped, potassium might give increases, due to the supplying of available material. The same results could undoubtedly be secured by the use of manure to stimulate available potassium production. The cost from the use of the manure would of course be much less. It seems doubtful if potassium would prove profitable on the soils of the county in general, except perhaps in small amounts as top dressings to encourage early growth.

The field tests now under way in Black Hawk county include tests of the use of a complete commercial fertilizer and when several years' data are available from these tests, it may be definitely determined whether these materials are profitable and whether they will prove as valuable as phosphorus carriers. At the present time complete brands of fertilizers cannot be recommended, inasmuch as there is no definite information available regarding their value. Farmers may test them along with acid and rock phosphate and determine their value. In fact, all tests should include a comparison with a phosphate to determine which is the more profitable. It seems doubtful whether the nitrogen and potassium contained in complete brands are necessary or of value, in-

*Bulletin 150, Iowa Agricultural Experiment Station.

Fig. 9. Tama silt loam topography. Clyde silty clay loam in draw

asmuch as nitrogen may be supplied more cheaply from inoculated legumes as green manures and potassium is present in such large amounts that sufficient can probably be made available by the ordinary desirable methods of soil treatment. If complete commercial materials prove profitable by actual tests in individual cases, however, there is no objection to their use and there will be no injury to the soil. It is entirely a question of profit, or in other words the cost of the material in comparison with the value of the increased crop growth. It must be kept in mind also that complete fertilizers should be tested with manure and lime or with crop residues and lime and not alone, if the test is to be of the most general value.

DRAINAGE

There is no very extensive need for drainage in Black Hawk county. In most cases the soils are naturally well drained and no difficulties in crop growth are experienced from excessive moisture. Among the upland types, the Clyde silty clay loam and the Webster loam are the only soils in need of artificial drainage. The Bremer silt loam and the Calhoun silt loam, terrace types, are poorly drained and the Wabash silt loam, heavy phase, and the areas of Meadow and Muck are the bottomlands which are not well drained. The use of tile drains would be desirable and profitable on all these types and in some cases without drainage there would be no possibility of securing anything like satisfactory crop yields in a normal season. It is the first treatment needed on these soils and without it other treatments will usually prove useless. The cost of tiling may be considerable in some cases but it is always a paying proposition for it determines many times whether a soil will yield a profitable crop or none at all. If there are small areas in any soil types in the county not mentioned which are too wet, tile should be installed there too. This can always be done with the assurance of profit, provided of course that the proper drainage of the area is followed by other necessary methods of soil treatment.

THE ROTATION OF CROPS

Many experiments have shown that the continuous growing of one crop is much less profitable in the long run than the use of a rotation. In fact in many instances soils have declined so rapidly under continuous cropping that farmers have been forced to adopt a rotation. Even if a certain crop is the "money" crop, it will not be profitable to grow that crop continuously but the actual income from the land will be greater where a rotation is followed If a soil is to be kept permanently fertile it is absolutely necessary that a rotation of crops be followed. Various rotations are in use thruout the state and while no one rotation can be recommended as the most desirable for the county, a choice may be made from among those listed below or some modification may be made which will fit the particular conditions. Almost any rotation may be employed provided it contains a legume. No rotation should be used which does not contain clover or some other leguminous crop because of the value of such crops in keeping up the supply of nitrogen and organic matter in the soil.

1—FOUR OR FIVE-YEAR ROTATION

First Year —Corn (with cowpeas, rape, or rye seeded in the standing corn at the last cultivation.

Second Year—Corn.

Third Year —Oats (with clover or with clover and timothy).

Fourth Year—Clover (if timothy was seeded with the clover the preceding year, the rotation may be extended to five years. The last crop will consist principally of timothy).

2—FOUR-YEAR ROTATION WITH ALFALFA

First Year —Corn.

Second Year—Oats.

Third Year —Clover.

Fourth Year—Wheat.

Fifth Year —Alfalfa (The crop may remain on the land five years. This field should then be used for the four-year rotation outlined above).

3—THREE-YEAR ROTATION

First Year —Corn.

Second Year—Oats or wheat (with clover seeded in the grain).

Third Year —Clover (Only the grain and clover seed should be sold. In grain farming most of the crop residues such as corn stover and straw should be plowed under. The clover may be clipped and left on the land to be returned to the soil).

THE PREVENTION OF EROSION

Erosion is the carrying away of soil thru the free movement of water over the surface of the land. If all the rain falling on the ground were absorbed, erosion could not occur, hence it is evident that the amount and distribution of rainfall, the character of the soil, the topography or "the lay of the land," and the cropping of the soil are the factors which determine the occurrence of this injurious action.

Slowly falling rain may be very largely absorbed by the soil, provided it is not already saturated with water, while the same amount of rain in one storm will wash the soil badly. When the soil is thoroly wet, the rain falling on it will of course wash over it and much soil may be carried away in this manner.

Light, open soils which absorb water readily are not apt to be subject to erosion while heavy soils such as loams, silt loams and clays may suffer much from heavy or long-continued rains. Loess soils are very apt to be injured by erosion when the topography is hilly or rough and it is this group of soils which is affected to the greatest extent in Iowa. Flat land is, of course, little influenced by erosion. Cultivated fields or bare bluffs and hillsides are especially suited for erosion while land in sod is not affected. The character of the cropping of the soil may therefore determine the occurrence of the injurious action. The careless management of land is quite generally the cause of the erosion in Iowa. In the first place, the direction of plowing should be such that the dead furrows run at right angles to the slope; or if that is impracticable, the dead furrows should be "plowed in" or across in such a manner as to block them. Fall plowing is to be recommended whenever possible as a means of preventing erosion. Only when the soil is clayey and absorption of water is very slow will spring plowing be advisable. The organic matter content of soils should be kept up by the addition of farm manures, green manures and crop residues if soil subject to erosion is to be properly protected. By the use of such materials the absorbing power of the soil is increased and they also bind the soil particles together and prevent their washing away as rapidly as might otherwise be the case. By all these treatments the danger of erosion is considerably reduced and expensive methods of control may be rendered unnecessary.

There are two types of erosion, sheet washing and gullying. The former may occur over a rather large area and the surface soil may be removed to such a large extent that the subsoil will be exposed and crop growth prevented. Sheet washing often occurs so slowly that the farmer is not aware of the gradual removal of fertility from his soil until it has actually resulted in lower crop yields. Gullying is more striking in appearance but is less harmful and it is usually more easily controlled. If, however, a rapidly widening gully is allowed to grow unchecked an entire field may soon be made useless for farming purposes. Fields may be cut up into several portions and the farming of such tracts is more costly and inconvenient.

In Black Hawk county erosion occurs to some extent in the Clinton silt loam and the Carrington sandy loam and in a few instances in some other types.

The means which may be employed to control or prevent erosion in Iowa may be considered under five headings, as applicable to "dead furrows", to small gullies, to large gullies, to bottoms, and to hillside erosion.

EROSION DUE TO DEAD FURROWS

Dead furrows or back furrows, when running with the slope or at a considerable angle to it, frequently result in the formation of gullies.

"Plowing In"—It is quite customary to "plow in" the small gullies that result from these dead furrows and in level areas where the soil is deep, this "plowing in" process may be quite effective. In the more rolling areas, however, where the soil is rather shallow, the gullies formed from dead furrows may not be entirely filled up by "plowing in." Then it is best to supplement the "plowing in" with a series of "staked in" dams or earth dams.

"Staking In"—The method of "staking in" is better as it requires less work and there is less danger of washing out. The process consists of driving in several series of stakes across the gully and up the entire hillside at intervals of from 15 to 50 yards, according to the slope. The stakes in each series should be placed three to four inches apart and the tops of the stakes should extend well above the surrounding land. It is then usually advisable to weave some brush about the stakes, allowing the tops of the brush to point up-stream. Additional brush may also be placed above the stakes, with the tops pointing up-stream, permitting the water to filter thru, but holding the fine soil in position where it is deposited.

Earth Dams—Earth dams consist of mounds of soil placed at intervals along the slope. They are somewhat higher than the surrounding land and act in much the same way as the stakes used in the "staking in" operation. There are some objections to the use of earth dams, but in many cases they may be quite effective in preventing erosion in "dead furrows."

SMALL GULLIES

Gullies result from the enlargement of surface drainageways and they may occur in cultivated land, on steep hillsides in grass or other vegetation, in the bottomlands, or at any place where water runs over the surface of the land. Small gullies may be filled in a number of ways but it is not practicable to fill them by dumping soil into them, for an immense amount of labor is involved and the effect will not be permanent.

"Staking In"—The simplest method of controlling small or moderate sized gullies and the one that gives the most general satisfaction is the "staking in" operation recommended for the control of deadfurrow gullies. The stakes should vary in size with the size of the gully, as should also the size and quantity of brush woven about the stakes. A modification of the system of "staking in" which has been used with success in one case consists in using the brush without stakes. The brush is cut so that a heavy branch pointing downward, is left near the top. This heavy branch is caught between a fork in the lower part of the brush pile, or hooked over one of the main stems and driven well into the ground Enough brush is placed in this manner to extend entirely across the gully, with the tops pointed downstream instead of upstream, which keeps it from being washed away as readily by the action of a large volume of water flowing upon it. A series of these brush-piles may be installed up the course of the gully and with the regular repair of washouts or undercuttings as they occur may prove very effective.

The Straw Dam—A simple method of preventing erosion in small gullies is to fill them with straw. This may be done at threshing time with some saving of time and labor. The straw is usually piled near the lower part of the gully, but if the gully is rather long or branching, it should be placed near the middle or below the junction of the branches or more than one dam should be used. The pile should be made so large that it will not wash out readily when it gets smaller thru decomposition and settling. One great objection to the use of straw is the loss of it as a feed, as a bedding material and as a fertilizer. Yet its use may be warranted on large farms which are operated on an extensive scale because of the saving in time, labor and inspection.

The Earth Dam—The use of an earth dam or mound of earth across a gully may be a satisfactory method of controlling erosion under some conditions. It will prove neither efficient nor permanent, however, unless the soil above the dam is sufficiently open and porous to allow of a rather rapid removal of water by drainage thru the soil. Otherwise too large amounts of water may accumulate above the dam and wash it out. In general it may be said that when not provided with a suitable outlet under the dam for surplus water the earth dam cannot be recommended. When such an outlet is provided the dam is called a "Christopher" or "Dickey" dam.

The "Christopher" or "Dickey" Dam—This modification of the earth dam consists merely in laying a line of tile down the gully and beneath the dam, an elbow or a "T" being inserted in the tile just above the dam. This "T", called a surface inlet, usually extends two or three feet above the bottom of the gully. A large sized tile should be used in order to provide for flood waters and the dam should be provided with a cement or board spillway or runoff to prevent any cutting back by the water flowing from the tile. The earth dam should be made somewhat higher and wider than the gully and higher in the center than at the sides to reduce the danger of washing. It is advisable to grow some crop upon it, such as sorghum, or even oats or rye, and later seed it to grass. Considering the cost, maintenance, permanence, and efficiency, the Christopher or Dickey dam, especially when arranged in series of two or more, may be regarded as the best method of filling ditches and gullies and as especially adapted to the larger gullies.

The Stone or Rubble Dam—Where stones abound they are frequently used in constructing dams for the control of erosion. With proper care in making such dams the results in small gullies may be quite satisfactory, especially when tile openings have been provided in the dam at various heights. The efficiency of the stone dam depends rather definitely upon the method of construction. If it is laid up too loosely, its efficiency is reduced and it may be washed out. Such dams can be used only very infrequently in Iowa.

The Rubbish Dam—The use of rubbish in controlling erosion is a method sometimes followed and a great variety of materials may be employed. The results are in the main rather unsatisfactory and it is a very unsightly method. Little effect in preventing erosion results from the careless use of rubbish even if a sufficient amount is used to fill the cut. The rubbish dam may be used, however, when combined with the Dickey system, just as the earth dam or stone dam, provided it is made sufficiently compact to retain sediment and to withstand the washing effect of the water.

The Woven Wire Dam—The use of woven wire, especially in connection with brush or rubbish, has cometimese proven satisfactory for preventing erosion in small gullies. The woven wire takes the place of the stakes, the principle of construction being otherwise the same as in the "staking in" system. It can only be recommended for shallow, flat ditches and in general other methods are somewhat preferable.

Sod Strips—The use of narrow strips of sod along natural surface drainageways may often prevent these channels from washing into gullies, as the sod serves to hold the soil in place. The amount of land lost from cultivation in this way is relatively small as the strips are usually only a rod or two in width. Bluegrass is the best crop to use for the sod, but timothy, redtop, clover or alfalfa may serve quite as well and for quick results sorghum may be employed if it is planted thickly. This method of controlling erosion is in common use in certain sections of the state and it might well be employed to advantage in many other places.

The Concrete Dam—One of the most effective means of controlling erosion is by the concrete dam, provided the Dickey system is used in connection with it. They are, however, rather expensive. Then, too, they may overturn if not properly designed and the services of an expert engineer are required to insure a correct design. Owing to their high cost and the difficulty involved in securing a correct design and construction, such dams cannot be considered as adapted to general use on the farm.

Drainage—The ready removal of excess water may be accomplished by a system of tile drainage properly installed. This removal of water to the depth of the tile increases the water absorbing power of the soil, and thus decreases the tendency toward erosion. Catch wells properly located over the surface and consisting of depressions or holes filled with coarse gravel and connected with the tile help to catch and carry away the excess water. In some places tiling alone may be sufficient to control erosion, but generally other means are also required.

LARGE GULLIES

The erosion in large gullies, which are often called ravines, may in general be controlled by the same methods as in the case of small gullies. The Christopher dam, already described, may also serve in the case of large gullies. The precautions to be observed in the use of this method of control have already been described and emphasis need only be placed here upon the importance of carrying the tile some distance down the gully to protect it from washing. The Dickey dam is the only method that can be recommended for controlling and filling large gullies and it seems to be giving very satisfactory results at the present time.

BOTTOMLANDS

Erosion frequently occurs in bottomlands and especially where such low-lying areas are crossed by small streams the land may be very badly cut up and rendered almost entirely valueless for farming purposes.

Straightening and Tiling—The straightening of the larger streams in bottomland areas may be accomplished by any community and while the cost is considerable, large areas of land may thus be reclaimed. In the case of small streams, tiling may be the only method necessary for reclaiming useless bottomland and it often proves very efficient.

Trees—Erosion is sometimes controlled by rows of such trees as willows which extend up the drainage channels. While the method has some good features it is not generally desirable. The row of trees often extends much further into cultivated areas than is necessary and tillage operations are interfered with. Furthermore, the trees may seriously injure the crops in their immediate vicinity because of their shade and because of the water which they remove from the soil. In general it may be said that in pastures, bottomlands and gulches the presence of trees may be quite effective in controlling erosion, but a row of trees across cultivated land or even extending out into it, cannot be recommended for very apparent reasons.

HILLSIDE EROSION

Hillside erosion may be controlled by certain methods of soil treatment which are of value, not only in preventing the injurious washing of soils, but in aiding materially in securing satisfactory crop growth.

Use of Organic Matter—Organic matter or humus is the most effective means of increasing the absorbing power of the soil and hence it proves very effective in preventing erosion. Farm manure may be used for this purpose or green manures may be employed if farm manure is not available in sufficient amounts. Crop residues such as straw, corn stalks, etc., may also be turned under in soils to increase their organic matter content. In general it may be said that all means which may be employed to increase the organic matter content of soils will have an important influence in preventing erosion and such means should not be overlooked.

Growing of Crops—The growing of crops, such as alfalfa, that remain on the land continuously for a period of two or more years is often advisable on steep hillsides. Alsike clover, sweet clover, timothy and redtop are also quite necessary for use in such locations. The root system of such crops as these hold the soil together and the washing action of rainfall is reduced to a marked extent.

Contour Discing—Discing around a hill instead of up and down the slope or at an angle to it is frequently very effective in preventing erosion. This practice is called ''contour discing'' and it has proven very satisfactory in many cases in Iowa. Contour discing is practiced to advantage on stalk ground in the spring preparatory to seeding small grain, and also on fall plowed land that is to be planted to corn. It is advisable in contour discing to do the turning row along the fence, up the slope, first, as the horses and disc when turning will pack and cover the center mark of the disc, thus leaving no depression to form a water channel.

Deep Plowing—Deep plowing increases the absorptive power of the soil and hence decreases erosion. It is especially advantageous if it is done in the fall as the soil is then put in condition to absorb and hold the largest possible amount of the late fall and early spring rains. It is not advisable, however, to change from shallow plowing to deep plowing at a single operation as too much subsoil may be mixed with the surface soil and the productive power of the soil therefore reduced. A gradual deepening of the surface soil by increasing the depth of plowing will be of value both in increasing the feeding zone of the plant roots and in making the soil more absorptive and therefore less subject to erosion.

INDIVIDUAL SOIL TYPES IN BLACKHAWK COUNTY*

There are twenty-nine individual soil types in Black Hawk county and areas of Meadow and Muck, making a total of thirty-one separate soil areas. These are divided into four large groups according to their origin. These groups are drift soils, loess soils, terrace soils and swamp and bottomland soils.

DRIFT SOILS

There are eight individual drift soils in the county. These are classed in the Carrington, Clyde, Webster and Thurston series.

CARRINGTON LOAM (1)

The Carrington loam is the largest drift soil and the second most extensive type in the county. It covers 103,859 acres or 28.7 percent of the total area of the county. It is the chief upland type thruout the northeastern part of the county, covering large areas north and east of the Cedar river. There are also numerous small areas occurring south and west of the river, the largest of these being found west of Waterloo.

The surface soil is a dark-brown to black loam which at 6 or 8 inches changes to a clay loam or silty clay loam. At 18 or 20 inches this becomes a yellowish-brown clay loam containing considerable coarse sand and gravel which below three feet becomes a yellowish-brown stony till. Large boulders occur thruout the type. On the steeper slopes near streams and in the vicinity of the Carrington sandy loam, the soil is sandier and lower in organic matter. It is therefore lighter in color and the subsoil is a compact brown stony clay loam. In the northern part of the county, on the broad upland areas between streams, the surface soil and subsurface soil are quite silty in character and the color is darker to a depth of 18 or 20 inches. In practically all the depressions and low spots in the type, the soil resembles the Clyde silty clay loam and many acres of this latter type, too small to show on the map, are included in the Carrington loam.

At the head of Poyner creek on the highest part of the upland there are some small areas included with the type, which are very thin and gravelly and have little agricultural value. Southeast of Hudson and in a few places west

*The descriptions of individual soil types given in this section of the report very closely follow those in the Bureau of Soils report

Note: There are some discrepancies on the boundary between Black Hawk county and Bremer county in the matter of some soil types. The Bureau of Soils explains these differences as follows:

"Black Hawk county lies immediately south of Bremer county. The latter county was surveyed in 1913, and all the terrace or second-bottom soils were mapped as Bremer regardless of the nature of their subsoils and of the character of their drainage, but experience gained since that time has shown that these soils are not all alike. Some are poorly drained, and others are very open in the subsoil, and subject to the drought. In recent surveys the droughty areas have been mapped as O'Neill soils, and those that are not droughty but are well drained are identified as Waukesha soils, while the Bremer series has been restricted to poorly drained, dark-colored second-bottom soils with subsoils rather heavier than the soil.

"On account of these necessary changes, due to a clearer understanding of the second-bottom soils, these soils on the Black Hawk county map do not correspond entirely to those on the Bremer county map. The O'Neill sandy loam on the Black Hawk map corresponds and joins up with the Bremer sandy loam on the Bremer map at one place and with the Cass sandy loam in another place. Neither the Bremer sandy loam nor the Cass sandy loam, as mapped in Bremer county, are true representatives of their respective series as defined in the recent surveys, but are both known to belong to the O'Neill series.

"The lack of uniformity in soil mapping on opposite sides of the county lines is an expression therefore of the advance made in the recognition of soil differences since 1913. It will be noted that the Fargo soils on the Bremer map join up with the Clyde soils on the Black Hawk map. It has been found since 1913 that the Fargo soils are higher in their content of lime carbonate than those in Bremer county, so that in later maps such soils are mapped as Clyde, a series that includes dark-colored, poorly drained soils low in lime carbonate.

"The Bremer loam areas mapped in the northwest corner of the county and those on the west side of the Wapsipinicon on the northern boundary of the county are both well drained and properly belong in the Waukesha series as now defined."

of Cedar Falls, there are moundlike hills which are composed of gravelly or stony till mixed with a thin surface silt loam, the lower surface soil being a loam. These mounds are extremely variable in texture but they always contain much coarse gravelly material.

About three miles northwest of Eagle Center is a variation from the main type, found on a rather narrow ridge occurring in the Tama silt loam. The surface soil to 6 or 8 inches is a dark grayish-brown, loose loam, containing considerable coarse sand and some small stones. This is underlain by a heavier loam which gradually changes into a yellowish-brown clay loam in the subsoil. There are other small ridges of this variation in the locality. In all these cases the surface soil is lighter in color and the subsoil is sandier in texture than the Tama soil but in normal seasons crop growth is very similar except on some stony or droughty patches.

In topography, the Carrington loam is generally gently rolling. In some areas between Mount Hope church and the north county line and between Crain creek and the small southward flowing streams, the type is quite level. Along some of the larger creeks, the surface is strongly rolling with some steep slopes but very little of the type is not easily cultivable. The surface drainage of most of the type is good and in general the underdrainage is quite adequate. Only in a few depressions where the soil is really Clyde silty clay loam is there any need for artificial drainage.

Practically all of the Carrington loam is under tillage, and general farm crops grow well. Corn yields 40 to 50 bushels per acre and under favorable seasonal conditions much higher yields are often secured. Oats average 30 to 40 bushels and frequently very much greater yields per acre. Timothy, bluegrass and clover generally do well.

The needs of this soil to make it more productive are in the first place the application of lime, for the soil is quite strongly acid in reaction. The organic matter supply is not low but applications of manure were shown in the greenhouse tests to be of distinct value on the soil. Farm experience confirms the recommendation that manure should be applied to this soil in as large amounts as practicable. If this material is not available in sufficient quantity, then leguminous green manures should be employed to keep up the supply of organic matter and nitrogen.

Phosphorus is not deficient now but there are indications that phosphorus fertilizers might be of value on this soil at the present time. These materials will undoubtedly be needed in the near future and tests of the relative value of rock phosphate and acid phosphate are highly desirable. Drainage may be needed on small areas and crop rotations should of course also be practiced. With these treatments the Carrington loam may be made more productive than it is at present and a high state of fertility may be maintained.

CLYDE SILTY CLAY LOAM (85)

The Clyde silty clay loam is the second largest drift soil but it is very much smaller in extent than the Carrington loam. It covers 28,672 acres or 7.9 percent of the total area of the county. This type occurs in practically all parts of the county, most of the areas being quite small. There is but one area of any considerable size and that occurs south of Washburn. In the northeastern part of the county it occurs in narrow sloughs, extending from the creek bottoms practically up to the uplands. The areas which are 15 or 20 rods wide are shown on the map but there are many smaller areas in this same section of the county which are too small to be mapped. The surface of these areas is apt to be hummocky and in places there are small areas of shallow Muck. Boulders are frequently found in considerable numbers. When such areas are drained, the soil becomes very productive. South of Washburn along Millers creek, there are wide, flat areas where the drainage is especially poor.

The surface soil of the Clyde silty clay loam is a black silt loam high in organic matter. A few inches below the surface this changes to a stiff, black silty clay loam, sticky and waxy when wet and coarsely granular when dry. At a depth of 30 inches or less the color becomes a lighter gray or drab with some yellow and brown mottling. This subsoil material is a clay loam containing considerable gravel and sand. In the narrow areas the subsoil is a sticky clay in most cases, with some stony material. In the larger areas of the type, however, particularly those along Millers creek, the subsurface material is a heavy silty clay loam with a dense gray subsoil at 30 or 40 inches. At 6 or 7 feet, sand or gravel or gravelly clay occurs.

The topography as a whole is rather flat to depressed and as has been indicated, the drainage is very poor owing to the impervious character of the subsoil material.

The chief need of this soil to make it productive is adequate drainage. When this is accomplished, good crop yields are secured, for the soil is naturally fertile. It is generally acid in reaction, and altho the particular sample tested in this work was basic there was no lime content in the soil and lime will soon be needed. In fact, other samples of the type quite generally show acidity. It is not so low in phosphorus as most of the other types but this element would soon be needed if the soil were brought under cultivation. Applications of farm manure, often in small amounts, would also be of value. With these treatments following thoro drainage, crops as large as those grown on the other uplands could be secured. At present most of the type is in pasture.

CARRINGTON SANDY LOAM (3)

The Carrington sandy loam is a minor type in the county, covering only 12,224 acres or 3.4 percent of the total area of the county. It occurs in many rather small areas, practically all of which are north and east of the Cedar river. There are also a few areas in the northwestern part of the county, west of the river. There are numerous extremely small spots of this type, some of which cannot be shown on the map.

The surface soil of this type is a dark brown, medium to fine sandy loam. The subsurface material is a lighter silt loam and below 18 to 20 inches this changes to a brown sand or loamy sand. Usually at 30 or 40 inches the material becomes a yellowish sandy clay. There are many variations in the type. Those areas occurring near the Carrington sand are rather rolling with a light colored sandy soil in the higher situations while the lower slopes are heavier and darker colored. Small areas of Carrington loam are frequently included. Some of the areas away from the larger streams have a rather dark colored surface soil and a heavy subsoil. There are other variations in the soil, chiefly in content of organic matter, in the texture of the subsurface soil and in the depth at which the heavy clay subsoil occurs.

In topography the Carrington sandy loam is usually gently rolling and the drainage is generally good. Even where the sandy lower subsoil is extensive, there seems to be a fair retention of moisture and in few instances is the soil droughty. It is subject to erosion in some of the more rolling areas.

Crop yields are quite variable, depending somewhat on seasonal conditions and also on the particular character of the soil. In the lighter, more sandy areas, there may be considerable drifting of the soil in dry windy weather. This is distinctly injurious to good crop growth. In the heavier areas, the crop yields may be quite satisfactory.

In general the need of this soil is primarily for more organic matter to increase its water-holding power, to prevent washing of the rolling areas and to supply plant food. The soil is low in nitrogen, which may also be supplied with the organic matter either as farm manure, leguminous green manures or both. Phosphorus is low and will need to be applied now or in the near future. The soil is acid and lime must be used if legumes are to be grown satisfactorily. With these treatments, the soil may be made fertile and kept so. No difficulty need then be experienced from drought or washing.

CARRINGTON SAND (119)

The Carrington sand is a minor drift type, covering 7,936 acres or 2.2 percent of the total area of the county. It occurs on ridges and mounds along the eastern side of the Cedar river, many of these areas being quite extensive. It often occurs in rounded dune-like ridges, rising 50 feet or more above the bottomlands.

The surface soil is a dark grayish-brown sand to a depth of 10 to 15 inches. It usually contains some silt and clay and has a slightly loamy character. The subsoil material is a loose, brown sand. This may extend for several feet but usually it is underlain at a depth of a few feet by yellow sandy clay. Stones and gravel occur in this lower subsoil material.

Most of the type along the Cedar river, south of Gilbertville, is wooded mainly with small oak. North of Waterloo, very little of the areas were ever forested. The agricultural value of the type is low, cultivation occurring only on the more shallow sandy areas or the small included areas of Carrington sandy loam. Rye, watermelons and early garden crops do well but corn is poor. Other crops are not successful and pasturage is poor. This soil should undoubtedly be used mainly for truck crops and garden crops. It should receive liberal applications of manure, or leguminous green manures should be turned under to increase its water-holding power and improve its fertility. Phosphorus fertilizers are needed and for garden crops complete commercial brands might prove very profitable. The type is acid in reaction and needs lime. By these treatments the soil may be kept from drifting, may be made to hold water and be less droughty and in general may be made to produce highly profitable truck or garden crops.

CARRINGTON FINE SANDY LOAM (4)

The Carrington fine sandy loam is a very minor type, covering 3,136 acres or 0.8 percent of the total area of the county. It occurs chiefly in two areas, one in the northwestern corner of the county and the other in the southeastern part. The area in the northwest consists of about three square miles, surrounded by Cedar valley and the bottomlands of Beaver creek. The southern area is found on the north side of the Cedar river, northeast of LaPorte City.

The surface soil is a very dark gray to black, mellow fine sandy loam grading into a dull-brown, moderately heavy but friable fine sandy loam. At 18 or 20 inches the soil becomes a yellowish-brown sandy loam or a fine sandy loam, which becomes gradually coarser with increasing depth. At a few feet yellowish-brown stony till is always found and this material may often occur within the 3-foot section.

In topography this soil is rolling to strongly rolling. The northern part of the area in the northwest corner of the state is strongly rolling and the soil is rather light colored. This portion of the type was originally timbered. The southern part of this area is much smoother and the soil is darker in color. The southeastern area is a rolling upland and the soil is a very friable dark-colored silty or fine sandy loam, and the subsoil is moderately heavy.

Practically all of the type is under cultivation and good average yields of general farm crops are secured. Corn averages 40 to 50 bushels, oats 50 to 60 bushels, and wheat 20 to 30 bushels per acre.

The soil is acid and in need of lime; the organic matter content is not high and applications of farm manure would be of much value; leguminous green manure crops should be used to supplement farm manure or as a substitute for it, and phosphorus fertilizers will be needed in the near future if they do not prove of value at the present time.

CARRINGTON SILT LOAM (83)

This is a minor soil in the county, covering only 1,421 acres or 0.4 percent of the total area of the county. The largest area is found in the uplands west of the Wapsipinicon river, near the north boundary of the county. Smaller areas occur at various place in the Carrington loam, most of which are too small to be mapped.

The surface soil of the Carrington silt loam is a very dark brown to black friable silt loam extending to a depth of 18 or 20 inches. Below this the texture of the soil becomes heavier and the subsoil is a yellowish-brown silty clay loam. At 30 or 40 inches this changes abruptly to a sandy clay or clay loam. In some of the areas east of the Wapsipinicon, there are small patches of a lighter colored soil due to a former growth of oak, hickory, elm and other trees. In topography this type is gently rolling and the drainage is usually quite adequate.

The Carrington silt loam is all under cultivation and crop yields are quite satisfactory. The soil is acid and lime is needed as shown in the greenhouse tests. Manure would prove of value and phosphorus fertilizers will probably be of use now or at least in the near future. Both the value of manure and of phosphorus fertilizers is shown in greenhouse tests. With these treatments the soil may be increased in productivity.

WEBSTER LOAM (55)

The Webster loam is a very minor type covering only 1,280 acres or 0.3 percent of the total area of the county. It occurs in several small areas in the northern part of the county occupying level or nearly flat areas in the Carrington loam on the upland.

The surface soil is a very black fine-textured or rather heavy silt loam. The subsoil below 18 to 24 inches is a silty clay somewhat lighter in color. The lower subsoil is usually a pale yellow clay or clay loam becoming more or less mottled with gray. The subsoil sometimes contains lime and gives a basic reaction.

This soil is very poorly drained and the first treatment necessary to make it properly productive is the installation of tile. When this has been done, lime should be used to neutralize acidity, applications of farm manure should be made and phosphorus fertilizers might prove of value. These latter materials will certainly be needed in the near future in all cases. With proper drainage and treatment these areas of Webster loam may be made as highly productive as the surrounding, more rolling, Carrington loam.

THURSTON LOAMY SAND (123)

This is a very minor type, covering only 1,216 acres or 0.3 percent of the total area of the county. It occurs in small areas in the northeast and southeast parts of the county.

The surface soil is a gray or slightly brownish-gray loamy sand which becomes a little more brownish and coarser in texture at lower depths. In the higher areas the soil is sandier while in the hollows and on the lower hillsides it is a silty loam. When dry the soil has an ashy-gray tint in practically all cases.

In the southeast part of the county, the areas occupy dune-like ridges where oak, wild cherry, elm and hickory formerly grew. The agricultural value of the Thurston loamy sand is low and crop yields are generally small. The soil is acid in reaction and needs lime. It is low in organic matter and should receive liberal applications of farm manure. With these treatments and applications of phosphorus fertilizers the crop yields can be increased to a profitable extent.

LOESS SOILS

There are five loess soils in the county, being classified in the Tama, Clinton and Dodgeville series.

TAMA SILT LOAM (120)

The Tama silt loam is the most extensive soil type in the county, covering 110,336 acres and with the rolling phase which is small in extent, covers 31.0 percent of the total area of the county. It is the chief upland type in the southwestern half of the county.

The surface soil is a friable silt loam, black when wet and dark brown or dark grayish-brown when dry. There is very little change in color or texture to a depth of 10 or 15 inches except that the soil becomes a little more compact. Below 18 or 20 inches, the color changes to brown or light brown and the texture to a silty clay loam plastic when moist and crumbly when dry. At about 35 inches, there is an abrupt change to a coarse gritty, yellowish-brown material, ranging in texture from a sandy loam to a clay loam. On the more sloping areas this coarse stony sandy clay ranges from 20 to 30 inches in depth, while on the tops of the ridges and on the more undulating uplands in the extreme southern part of the county, it is 40 or 50 inches in thickness.

The topography of the type is in general undulating to gently rolling. On the eastern side of Black Hawk creek and on some of the slopes to the Cedar river, the topography is more strongly rolling but in no case is there any difficulty in cultivation and there seems to be practically no erosion. The drainage of the Tama silt loam is excellent and there seems to be no necessity for artificial drainage.

The entire area of the soil is cultivated and crop yields on the whole are quite satisfactory. Corn averages about 50 bushels per acre and oats about the same. Larger yields of both crops are frequently secured in favorable seasons. Clover and timothy do well and alfalfa should prove a profitable crop if the soil is properly prepared.

The Tama silt loam is acid in reaction and applications of lime are quite necessary, especially if legumes such as clover or alfalfa are to be successfully grown. Manure proved very profitable on the type in the greenhouse test and the use of this material in as large amounts as practicable should be recommended. In case farm manure is not available in sufficient amounts, leguminous green manures should be employed to increase the supply of organic matter and nitrogen in the soil. Phosphorus fertilizers showed value in the greenhouse tests and applications of these materials probably would prove profitable in the field. Tests of both acid phosphate and rock phosphate should be made before large areas are treated. These treatments will make and keep this soil highly productive.

TAMA SILT LOAM (Rolling phase) (121)

The Tama silt loam, rolling phase, is a very minor type, covering only 1,792 acres or 0.5 percent of the total area of the county. It occurs on the upland slopes west of Black Hawk creek in two large areas and in several other very small areas.

The surface soil on the higher ground is generally a dark brown sandy loam with a yellowish-brown loam or silt loam subsoil, which at 30 to 40 inches grades into a comparatively loose, brown sand. On the lower slopes and wider ridges it varies from a sandy loam to a silt loam and is extremely variable. In topography, this phase is strongly rolling to hilly and sometimes the hills are too steep for satisfactory cultivation. The soil is well drained.

The type is lower in producing power than the typical Tama silt loam but with proper treatment, practically all of it may be made as fertile as the surrounding upland. It is acid and in need of lime. It is particularly in need of organic matter and farm manure should be applied in liberal amounts, or leguminous green manures employed. Phosphorus is low and phosphorus fertilizers would probably be of value now and certainly will be needed in the near future.

CLINTON SILT LOAM (80)

The Clinton silt loam is a minor type, covering 2,880 acres or 0.8 percent of the total area of the county. It is confined to a few areas of high rolling upland above the larger valleys. The largest area occurs northwest of Waterloo and narrow strips of the type are found along the west side of the river above Cedar Falls and in the southeastern part of the county on the east of the river valley.

The surface soil is a light gray or grayish-brown silt loam which is very friable when dry. This is often covered by a layer of leaf mold, 2 to 3 inches in thickness, in the wooded areas. At a depth of 12 to 18 inches the color varies from a light brown or buff to a slightly reddish-brown and the soil contains more clay and may grade into a silty clay loam. At varying distances of from 3 feet on the steeper slopes to several feet on the ridges, the yellowish-brown till is encountered. In areas adjoining the Tama silt loam and in depressions, the soil is darker in color than the typical. In some areas there is very little sand in the surface soil, and it becomes very compact after rains. The areas in the southern part of the county are not typical, varying from a silt loam to a fine sandy loam and in many places the soil is rather dark in color and very little different in crop production from the surrounding black soils.

The type was all originally forested with oak, hickory, linden, wild cherry and other trees common to the region and it is still largely in timber. Where cultivated, the crop yields are usually lower than on the surrounding upland soils but on the darker colored better areas, the general farm crops produce satisfactorily, grain and clover usually doing well on such areas. The type is well adapted to the growth of apples, pears and cherries and at Cedar Heights many small fruits are profitably productive.

The soil is acid and in need of lime. The organic matter content is very low in most cases and heavy applications of farm manure would prove profitable. Leguminous green manures might also be used with value in many cases. Phosphorus is low and should be supplied by the use of phosphorus fertilizers. The soil is subject to some erosion and care should be taken to prevent such destructive action.

CLINTON FINE SANDY LOAM (122)

This is a minor type, covering only 1,792 acres or 0.5 percent of the total area of the county. The largest area occurs on the east side of the Wapsipinicon valley near the Buchanan county line in the northeastern part of the county. Small areas are found also on the uplands east of the Cedar river near McChane.

The surface soil is generally a light fine sandy loam overlying brown sandy material. Many variations occur, however. Near the Carrington sandy loam, the type is very similar to that soil. Sometimes it is a friable silty loam with a yellow clay or clay loam subsoil. In depressions it is much darker in color and in some sloughs it resembles the Clyde silty clay loam.

The larger part of the type is now under cultivation. Some is still forested with red and black oak and some bur oak. General farm crops, corn, oats and clover give good yields in seasons of abundant rainfall. Near McChane, much sweet corn is successfully grown on this soil as well as on the Clinton silt loam.

The soil is extremely low in organic matter and should receive liberal applications of farm manure and probably also green manures. It is acid in reaction and should be limed and as the phosphorus content is low it would probably also respond profitably to phosphorus fertilizers.

DODGEVILLE SILT LOAM (Shallow phase) (104)

This is an extremely minor type in the county, covering only 384 acres or 0.1 percent of the total area of the county. It occurs in a few small areas on the uplands west of the Cedar river near LaPorte City and along Miller's creek northeast of Eagle Center.

The soil is very similar to the Tama silt loam except that it is underlain by limestone at a depth of a few feet. In some small areas the surface soil is a sandy loam rather than a silt loam. On the steeper slopes the underlying lime rock is exposed but in general it is not. Some quarries are being worked to supply lime for local use.

Crop production on this soil is very much the same as that on the Tama silt loam. It is acid and needs lime in the surface soil. The subsoil it also acid, the underlying limestone having no effect on the soil. It will respond to organic matter and probably also to phosphorus fertilizers.

TERRACE SOILS

There are eleven terrace soils in Black Hawk county and they are classed in the O'Neill, Waukesha, Bremer, and Calhoun series.

O'NEILL COARSE SANDY LOAM (125)

The O'Neill coarse sandy loam is the most extensive terrace type. It covers 14,784 acres or 4.1 percent of the total area of the county. It occurs on the terraces along the Cedar river on both the east and west sides. The largest area is north of Cedar Falls. Small areas are also found along the Wapsipinicon river.

The surface soil varies from a grayish-brown coarse loamy sand to a dark brown, moderately heavy sandy loam. In general it is a coarse textured, loose sandy loam. In many places there is much small, rounded gravel. The subsurface soil is a little heavier than the surface, slightly more compact and darker colored. At a depth of about 20 to 30 inches, in general, there is coarse sand and gravel which may extend to considerable depths. In the areas of a heavier texture, the soil has a very dark brownish tint down to the subsoil sand and gravel. These heavier areas usually occur in level or slightly depressed spots. On the slight elevations, the soil is lighter in color.

In topography the soil is rather uneven, being characterized by local elevations and depressions. On the largest areas near Cedar Falls there are several different levels. Near Waterloo the areas are smooth plains with a gentle slope toward the upland. South of Waterloo they are lower and the soil consists of somewhat finer materials. The type is all above overflow and the drainage is good to excessive.

Practically all of the O'Neill coarse sandy loam is under cultivation. Rye is one of the chief crops grown and yields range from a few bushels to 15 or

20 bushels per acre. Corn produces yields of 25 to 30 bushels in favorable seasons. Sweet corn is grown to some extent and watermelons prove successful. Sudan grass, feterita and sorghum are also grown to some extent. Near Winslow the latter crop has been grown for several years on 200 to 300 acres.

The soil is low in organic matter and farm manure should be applied in liberal amounts. Leguminous green manures would probably also prove of value, in many cases. The use of such materials is particularly desirable in order to increase the water-holding power of the soil and reduce the danger of injury to crops from drought. The soil is acid and in need of lime, especially if legumes are to be grown. Phosphorus fertilizers did not show any value in the greenhouse tests but the content of phosphorus in the soil is low and these materials will need to be used in the near future. In favorable seasons crop yields may be satisfactory but in general the soil is apt to be droughty and should be so handled and treated that the moisture conditions are kept at the best.

WAUKESHA LOAM (60)

This is the second largest terrace type in the county, covering 11,904 acres or 3.3 percent of the total area of the county. A large area is found on the east side of Black Hawk creek. Other areas occur along the Cedar river, along Elk run and in the valley of the Wapsipinicon.

The surface soil is a dark brown to black, moderately heavy loam, containing more or less coarse material, and generally friable to crumbly in structure. At 15 to 20 inches, the color is usually a pronounced brown and the texture of the soil changes to a light loam or sandy loam. Below 40 inches there is a layer of sand or gravel. The surface soil texture varies somewhat, being sometimes a sandy loam near the streams. This is true in the area along Black Hawk creek. In some areas below Washburn, gravel occurs nearer the surface and the soil is inclined to be droughty. Near the river the areas are fine textured loams, generally heavier than those on the higher terraces. Near Laporte City the areas are black loams to sandy loams with rather heavy subsoils. The areas mapped in the northern part of the county are low terraces, including poorly drained swales and spots where a heavy black silty clay subsoil occurs and makes cultivation difficult. Along Elk run the soil is a dark colored loam to sandy loam and lower in organic matter than the areas along the Cedar river.

In general the soil is rather level in topography and except for the few small areas mentioned above, the drainage is quite adequate. The type is well above overflow in practically all areas.

General farm crops are grown and yields are good. Corn averages 50 to 60 bushels in favorable seasons. The soil is acid and in need of lime. It is not particularly low in organic matter but applications of farm manure would prove distinctly profitable. Phosphorus is not high and if the best crop yields are to be secured phosphorus fertilizers will be needed in the future if they do not prove profitable now.

WAUKESHA SILT LOAM (75)

The Waukesha silt loam is about equal in area to the Waukesha loam, covering 11,584 acres or 3.2 percent of the total area of the county. It occurs on terraces along the rivers and the larger tributaries, in many rather large areas and numerous small areas.

The surface soil is a very friable silt loam, varying in color from a dark grayish-brown when dry to nearly black when wet. At 10 to 15 inches the color changes to a light brown or yellowish-brown which remains the same for several feet. The subsurface soil is chiefly silt but the amount of clay increases somewhat and the subsoil may be a silty clay loam.

The lower subsoil is not so heavy and consists chiefly of silt and silty fine sand. The areas along Miller's creek, those near Laporte City and most of the small areas near Cedar Falls bear a very close resemblance to the Tama silt loam. Along Black Hawk creek, the soil near the hills is a dark, heavy silt loam but nearer the stream it is a loam and some spots are quite sandy.

In topography the Waukesha silt loam is rather level, usually having a gentle slope toward the streams. In some areas the natural drainage is slow but in general tile is not needed.

Crop yields on this soil are generally very good. Corn averages 50 bushels per acre while oats, barley, clover and other crops yield about the same as on the uplands.

The soil is acid and should receive applications of limestone. It is not low in organic matter but farm manure should be applied to keep up the supply and it will prove of distinct value. Phosphorus fertilizers may not be of value now but they will soon be required, for the soil is low in phosphorus. Tests of these materials should be made on this type.

O'NEILL SANDY LOAM (126)

The O'Neill sandy loam is a minor type, covering 6,528 acres or 1.8 percent of the total area of the county. It occurs in many areas along the Cedar river and also along the Wapsipinicon river, occupying high terraces, well above overflow.

The surface soil is very similar to the O'Neill coarse sandy loam except that it is finer in texture. In the lightest textured places it is a grayish-brown loamy sand while in the heavier areas it is a moderately heavy sandy loam rather dark in color. Below 18 to 20 inches there is a loose brown medium to coarse sand gradually becoming somewhat lighter in color. Below 40 inches, there occurs the typical layer of gravel.

This soil holds moisture better than the coarse sandy loam and is less subject to injury by drought. Corn yields 25 to 30 bushels per acre in good seasons. Clover and oats yield quite satisfactorily on the heavier areas. Melons and truck crops should grow well.

The need of this soil is chiefly for more organic matter to keep it in better physical condition and better able to hold moisture and withstand drought. Farm manure should be used in large amounts and green manures would probably also prove of value in many cases. The soil is acid and should receive applications of lime, especially if legumes are to be grown for green manures. Phosphorus is low and phosphorus fertilizers would probably prove of value. They will certainly be needed in any case, in the near future.

BREMER LOAM (12)

The Bremer loam is a minor type covering 4,096 acres or 1.1 percent of the total area of the county. It occurs in many small areas on the terraces of the Cedar river, Elk run and the Wapsipinicon river. In the latter location it occupies flat or slightly depressed areas and often has a hummocky surface. The narrow areas are swales or drainageways. In Elk run valley the type occurs in low swales and flats and resembles the Clyde silty clay loam. The narrow areas of the type below Waterloo occupy old channels which have been nearly filled, and the same is true of the areas near Cedar Falls.

The soil varies from a sandy loam to a heavy loam, very dark in color. The subsoil is a light-colored clay loam or sandy clay mottled with yellow and brown. The lower subsoil at a depth of several feet is gravel. The areas near Dunkerton are generally coarser textured while in other areas the soil is a loam or silt loam with a black granular clay subsoil changing at lower depths into an impervious light-colored clay.

The topography of the Bremer loam is level to flat and the drainage is extremely poor. The soil is used mainly for pasture but if properly drained it should permit of the growth of satisfactory crops of corn, oats and other crops.

The chief need of the soil at present is for thoro drainage. The installation of tile and drainage ditches has proved very profitable in many cases. Much tile drainage is still necessary, however. The soil is acid and in need of lime; farm manure in small applications after drainage would prove of value in stimulating the production of available plant food, and phosphorus fertilizers will be needed in the near future.

BREMER SILT LOAM (88)

This is a minor type covering 2,176 acres or 0.6 percent of the total area of the county. It occurs on low terraces, chiefly along Black Hawk creek altho there are small areas in other parts of the county.

The surface soil is a black, mellow silt loam, containing little sand or gravel. This changes to a somewhat heavier crumbly silty clay loam at 6 to 8 inches. In the lower part of the 3-foot section, the subsoil is a light-colored clay loam containing some sand and gravel, varying in color from a dark drab to gray, mottled with yellow and brown.

The soil is especially in need of drainage and tile should be installed. When this is accomplished excellent crop yields are obtained. The soil is acid and needs lime. Farm manure would prove of value on newly drained areas and phosphorus fertilizers will be needed soon.

O'NEILL SAND (124)

The O'Neill sand is a very minor type, covering 2,112 acres or 0.6 percent of the total area of the county. It occurs on low mounds and ridges associated with the O'Neill sandy loam, mainly between Cedar Falls and Janesville. The larger areas are narrow ridges, 10 to 20 feet above the terrace surface and the small areas are low irregular mounds, 10 to 15 feet in height.

The surface soil is a medium to coarse sand, ranging in color from brown or grayish-brown to gray. At 1 to 2 feet this passes into a lighter colored sand which extends to a considerable depth unchanged.

Most of the type is cultivated. Rye grows fairly well. Watermelons and cantaloupes are quite satisfactory crops. Corn yields poorly. This soil is subject to excessive drainage and crops suffer from drought. It is extremely low in organic matter and needs liberal applications of farm manure. Green manures would also prove of value in increasing the ability of the soil to hold moisture. It is acid and should be limed and phosphorus fertilizers will soon be needed if they are not of value now.

O'NEILL LOAM (108)

This type is of minor importance covering only 1,472 acres or 0.4 percent of the county. It occurs on high terraces along Spring creek.

The surface soil is a moderately heavy, dark colored loam to sandy loam. The subsoil is slightly heavier consisting usually of a rather light loose loam which changes to a light brown sandy loam. This is underlaid by a brown sand or gravel which usually occurs within 40 inches from the surface. Near the creek, it is rather coarse silt loam and coarse yellow sand is frequently found. Back from the stream, the soil is heavier.

The type is injured by drought and it should be supplied with large amounts of farm manure or green manures to enable it to retain more moisture. Lime is needed to remedy acidity and phosphorus fertilizers will soon be required. With these treatments general farm crops may be grown successfully.

WAUKESHA SANDY LOAM (127)

This soil is of small extent, covering 1,344 acres or 0.4 percent of the county. It occurs on low terraces along the smaller streams. Along Elk Run the areas consist of low sandy ridges in the Bremer loam.

The surface soil is a dark-brown or brownish-gray sandy loam. The subsoil is a brown, medium to coarse sandy loam. The lower subsoil at 4 or 5 feet is gravel. The soil is usually well drained and in some areas the drainage is excessive. As a rule, however, it is not a droughty soil.

The needs of the Waukesha sandy loam are for lime to remedy acidity, for farm manure or green manures to increase the organic matter supply and for phosphorus fertilizers.

WAUKESHA FINE SANDY LOAM (128)

This type covers only a small area in the county, 960 acres or 0.3 percent of the total area of the county. It is found in a few small areas north of Cedar Falls and south of Washburn. In the former location it occurs in some long narrow strips which occupy low ridges. There are a few wider areas. South of Washburn the areas are rather high ridges.

The soil is a dark brown, friable fine sandy loam, changing little to 18 or 20 inches. Below that point it becomes a dull brown friable fine sandy loam, gradually changing to a lighter color and containing less silt at lower depths. South of Washburn the soil varies from a fine sandy loam to a silt loam.

The Waukesha fine sandy loam is all cultivated and crop yields are much the same as on the silt loam. The soil needs lime, farm manure to supply organic matter and probably also phosphorus fertilizers.

CALHOUN SILT LOAM (42)

This type occupies only 128 acres, or 0.1 percent of the total area of the county. It occurs in one area east of the Wapsipinicon river, just south of the north boundary line of the county.

The soil is a gray silt loam overlying a light gray silt loam with yellow mottlings. Below that there is a light yellow or somewhat mottled gray and pale yellow silty clay which is very compact and impervious. Gravel usually occurs both in the surface soil and subsoil.

A part of the type is cultivated and satisfactory crop yields are secured in seasons of normal rainfall. The soil is poorly drained and tile drainage is the chief treatment needed. It should also receive liberal applications of farm manure or green manures, lime should be applied and phosphorus fertilizers will be needed.

SWAMP. AND BOTTOMLAND SOILS

There are seven areas of swamp and bottomland soils, five types of the Wabash and Cass series and areas of Meadow and Muck.

MEADOW (20)

The largest area of bottomland is included in the area of Meadow. It covers 19,136 acres or 5.3 percent of the total area of the county. The most extensive areas accur along the Cedar river, occupying the larger part of the bottomland. There are also areas adjoining some of the other streams.

Meadow includes soils which are so variable in character that they cannot be classified into types. In some places, on the inner side of the sharper curves of the streams, the soil is mainly sand while in the wider areas, it is a loose, dark colored loam or even a silty clay. Along the Wapsipinicon it is generally a sandy soil.

The areas of Meadow are generally forested with oak, hickory, ash, walnut, and maple. It is subject to frequent overflow and is mainly used for pasture. In some areas where it is cultivated, good crop yields are secured.

WABASH LOAM (49)

The Wabash loam is a minor type covering 2,944 acres or 0.8 percent of the total area of the county. It occurs in areas along the Cedar river in the northwestern part of the county and along Crain creek in the northeast.

The soil ranges in texture from a silty to a sandy loam but most of the type is a rather heavy black loam crumbly or granular in structure. The subsoil is often a dull brown loam or silt loam with some mottling. Along Crain creek the soil is not typical Wabash loam. In part it is a dark colored loam with a rather heavy subsoil underlain at several feet by gravel. At other places it is frequently a heavy loam to silt loam with a stiff clay, silty clay or clay loam subsoil. Gravel occurs at a depth of a few feet.

The type is subject to frequent overflow along Crain creek but in the Cedar river valley it is overflowed only occasionally when higher floods occur. In the latter location it is cultivated and when not overflowed yields good crops of corn, oats and clover. Along Crain creek the type is mainly used for pasture but some sections are cultivated. Very little of the soil is timbered, except for willows along the creek channel.

This soil needs mainly protection from overflow and drainage if it is to be cultivated successfully. Lime is necessary to remedy acidity, manure must be used and phosphorus fertilizers will be required.

CASS SANDY LOAM (19)

The Cass sandy loam is a minor type, covering 2,176 acres or 0.6 percent of the total area of the county. It occurs in many small areas along the Cedar river and along the Wapsipinicon.

The surface soil is a very dark colored moderately coarse sandy loam. The subsurface soil is usually somewhat heavier, often a loam or silty loam. The subsoil is loose, brown sand. There is much variation in the character of the surface soil and in the depth at which the brown sand occurs. In the higher spots the soil may be a light loam while in depressions it may be so heavy that it will clod when plowed wet.

The type is subject to overflow and changes somewhat in character with each deposition. A large part of the soil is cultivated, corn being the chief crop grown. Yields are often high but the crop is often lost by high water in summer. The drainage of the soil is usually quite adequate.

This soil needs chiefly protection from overflow to insure good crop growth. It may be acid in some cases altho the sample tested in this work was not. There was no large occurrence of lime, however, and lime will soon be needed. The use of farm manure would be profitable and phosphorus fertilizers will undoubtedly be needed in the future.

WABASH SILT LOAM (26)

This is a minor type, covering 1,024 acres and with the heavy phase constituting only 0.5 percent of the total area of the county. The largest areas occur along Black Hawk creek below Hudson. There are several other smaller areas in the Cedar river valley.

The surface soil is a black friable or mellow silt loam. The dark color persists to 20 inches and the soil is a black silty clay inclined to be stiff and sticky when wet. The lower part of the 3-foot section contains more sand and is yellowish-brown in color with some mottling.

The type is used only for pasture, and blue-grass and white clover do well in the higher acreas while coarse grasses mainly are found in the low spots. It is poorly drained.

This soil is subject to overflow and if it is to be cultivated it should be protected from overflow and then drained. It is acid and would need lime. Farm manure should be used and eventually phosphorus fertilizers.

WABASH SILT LOAM (Heavy phase) (129)

This type is very small in area, covering but 640 acres or 0.2 percent of the total area of the county. It occurs along Black Hawk creek.

The soil is a black silt loam or silty clay loam changing at a few inches to a stiff, heavy silty clay which continues about the same to a depth of 3 feet. In the poorly drained spots the lower subsoil may be a light drab silty clay.

The soil is flat or slightly depressed and is very poorly drained. It is subject to overflow and is used mainly for pasture. If cultivated it should be protected from overflow and drained. Lime should be applied and farm manure and phosphorus fertilizers would also probably prove profitable.

CASS LOAM (18)

The Cass loam is a very small type, covering but 1,472 acres or 0.4 percent of the total area of the county. It occurs mainly in two areas, one south of Waterloo and one east of Cedar Falls. There are also other very small areas.

The soil is generally a very dark colored loam or sandy loam altho in places it is quite clayey. At varying depths the subsoil of brown sand or sandy loam is encountered, usually becoming lighter with increase in depth.

The soil is subject to overflow and is used chiefly for pasture. It is well drained, however, and if protected from overflow, limed and manured, it would undoubtedly produce good crop yields.

MUCK (21a)

There is a small acreage of Muck in the county, amounting all together to 192 acres or 0.1 percent of the total area of the county. There are many small areas in various parts of the county, the largest covering from 15 to 20 acres.

Muck is a black, finely divided organic material produced by the decomposition of vegetation which has accumulated in old ponds and lake beds. The depth of the muck is variable, ranging from a few inches at the edge of the spots to 3 or 4 feet in the center. Areas of shallow Muck consisting of a clay loam with a high content of vegetation residues in the surface few inches are included in the Clyde silty clay loam.

Muck is found in low spots and is usually in need of drainage. Timothy and bluegrass often do well but timothy and alsike clover are more desirable. When drained, Muck will produce good crops of cabbage, onions, celery and other truck crops. Grain crops ordinarily grow to stalk and lodge badly. After being drained and pastured or cultivated for several years, however, general farm crops may grow successfully. Muck is acid and needs lime. Phosphorus is low and will need to be supplied and potassium fertilizers might also be profitable. Small amounts of farm manure help the reclamation of such spots.

APPENDIX

THE SOIL SURVEY OF IOWA

What soils need to make them highly productive and to keep them so, and how their needs may be supplied are problems which are met constantly on the farm today.

To enable every Iowa farmer to solve these problems for his local conditions, a complete survey and study of the soils of the state has been undertaken, the results of which will be published in a series of county reports. This work includes a detailed survey of the soils of each county, following which all the soil types, streams, roads, railroads, etc., are accurately located on a soil map. This portion of the work is being carried on in cooperation with the Bureau of Soils of the United States Department of Agriculture.

Samples of soils are taken and examined mechanically and chemically to determine their character and composition and to learn their needs. Pot experiments with these samples are conducted in the greenhouse to ascertain the value of the use of manure, fertilizers, lime and other materials on the various soils. These pot tests are followed in many cases by field experiments to check the results secured in the greenhouse. The meagerness of the funds available for such work has limited the extent of these field studies and tests have not been possible in each county surveyed. Fairly complete results have been secured, however, on the main soil types in the large soil areas.

Following the survey, systems of soil management which should be adopted in the various counties and on the different soils are worked out, old methods of treatment are emphasized as necessary or their discontinuance advised, and new methods of proven value are suggested. The published reports as a whole will outline the methods which the farmers of the state must employ if they wish to maintain the fertility of their soils and insure the best crop production.

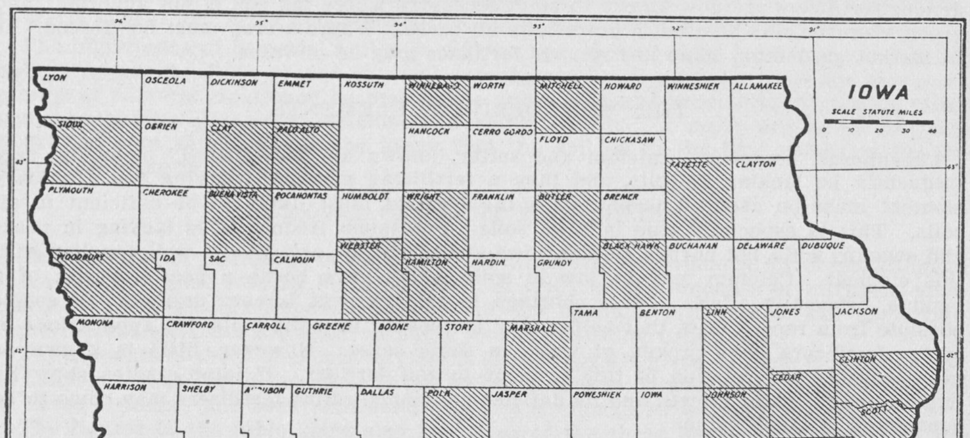


Fig. 10. Map of Iowa showing the counties surveyed

The various counties of the state will be surveyed as rapidly as funds will permit, the number included each year determined entirely by the size of the appropriation available for the work. The order in which individual counties will be chosen depends very largely upon the interest and demand in the county for the work. Petitions signed by the residents, and especially by the farmers or farmers' organizations of the county, should be submitted to indicate the sentiment favorable to the undertaking. Such petitions are filed in the order of their receipt and aid materially in the annual selection of counties.

The reports giving complete results of the surveys and soil studies in the various counties will be published in a special series of bulletins, as rapidly as the work is completed. Some general information regarding the principles of permanent soil fertility and the character, needs and treatment of Iowa soils, gathered from various published and unpublished data accumulated in less specific experimental work will be included in or appended to all the reports.

PLANT FOODS IN SOILS

Fifteen different chemical elements are essential for plant food, but many of these occur so extensively in soils and are used in such small quantities that there is practically no danger of their ever running out. Such, for example, is the case with iron and aluminum, past experience showing that the amount of these elements in the soil remains practically constant.

Furthermore, there can never be a shortage in the elements which come primarily from the air, such as carbon and oxygen, for the supply of these in the atmosphere is practically inexhaustible. The same is true of nitrogen, which is now known to be taken directly from the atmosphere by well-inoculated legumes and by certain microscopic organism. Hence, altho many crops are unable to secure nitrogen from the air and are forced to draw on the soil supply, it is possible by the proper and frequent growing of well-inoculated legumes and their use as green manures, to store up sufficient of this element to supply all the needs of succeeding non-legumes.

Knowledge of the nitrogen content of soils is important in showing whether sufficient green manure or barnyard manure has been applied to the soil. Commercial nitrogenous fertilizers are now known to be unnecessary where the soil is not abnormal, and green manures may be used in practically all cases. Where a crop must be "forced," as in market gardening, some nitrogenous fertilizer may be of value.

THE "SOIL DERIVED" ELEMENTS

Phosphorus, potassium, calcium and sulfur, known as "soil-derived" elements, may frequently be lacking in soils, and then a fertilizing material carrying the necessary element must be used. Phosphorus is the element most likely to be deficient in all soils. This is especially true in Iowa soils. Potassium frequently is lacking in peats and swampy soils, but normal soils in Iowa and elsewhere are usually well supplied with this element. Calcium may be low in soils which have borne a heavy growth of a legume, especially alfalfa; but a shortage in this element is very unlikely. It seems possible from recent tests that sulfur may be lacking in many soils, for applications of sulfur fertilizers have proven of value in some cases. However, little is known as yet regarding the relation of this element to soil fertility. If later studies show its importance for plant growth and its deficiency in soils, sulfur fertilizers may come to be considered of much value.

If the amounts of any of these soil-derived elements in soils are very low, they need to be supplied thru fertilizers. If considerable amounts are present, fertilizers containing them are unnecessary. In such cases if the mechanical and humus conditions in the soil are at the best, crops will be able to secure sufficient food from the store in the soil. For example, if potassium is abundant, there is no need of applying a potassium fertilizer; if phosphorus is deficient, a phosphate should be applied. If calcium is low in the soil, it is evident that the soil is acid and lime should be applied, not only to remedy the scarcity of calcium, but also to remedy the injurious acid conditions.

AVAILABLE AND UNAVAILABLE PLANT FOOD

Frequently a soil analysis shows the presence of such an abundance of the essential plant foods that the conclusion might be drawn that crops should be properly supplied for an indefinite period. However, application of a fertilizer containing one of the elements present in such large quantities in the soil may bring about an appreciable and even profitable increase in crops.

The explanation of this peculiar state of affairs lies in the fact that all the plant food shown by analyses to be present in soils is not in a usable form; it is said to be *unavailable*. Plants cannot take up food unless it is in solution; hence *available* plant food is that which is in solution. Analyses show not only this soluble or available portion but also the very much larger insoluble or unavailable part. The total amount of plant food in the soil may, therefore, be abundant for numerous crops, but if it is not made available rapidly enough, plants will suffer for proper food.

Bacteria and molds are the agents which bring about the change of insoluble, unavailable material into an available form. If conditions in the soil are satisfactory for their vigorous growth and sufficient total plant food is present, these organisms will bring about the production of enough soluble material to support good crop growth. The soil conditions necessary for the best growth and action of bacteria and molds are the same as those which are required by plants. The methods necessary to maintain permanent soil fertility will, therefore, insure satisfactory action of these organisms and the sufficient production of available plant food. The nitrogen left in the soil in plant and animal remains is entirely useless to plants and must be changed to be available. Bacteria bring about this change and they are all active in normal soils which are being properly handled.

Phosphorus is found in soil mainly in the mineral known as apatite and in other insoluble substances. Potassium occurs chiefly in the insoluble feldspars. Therefore, both of these elements, as they normally occur in soils, are unavailable. However, the growth of bacteria and molds in the soil brings about a production of carbon dioxide and organic acids which act on the insoluble phosphates and potassium compounds and make them available for plant food.

Calcium occurs in the soil mainly in an unavailable form, but the compounds containing it are attacked by the soil water carrying the carbon dioxide produced by bacteria and molds and as a result a soluble compound is formed. The losses of lime from soils are largely the result of the leaching of this soluble compound.

Sulfur, like nitrogen, is present in soils chiefly in plant and animal remains, in which form it is useless to plants. As these materials decompose, however, so-called sulfur bacteria appear and bring about the formation of soluble and available sulfates.

The importance of bacterial action in making the store of plant food in the soil available is apparent. With proper physical and chemical soil conditions, all the necessary groups of bacteria mentioned become active and a vigorous production of soluble nitrogen, phosphorus, potassium, calcium and sulfur results. If crops are to be properly nourished care should always be taken that the soil be in the best condition for the growth of bacteria.

REMOVAL OF PLANT FOOD BY CROPS

The decrease of plant food in the soil is the direct result of removal by crops, although there is often some loss by leaching also. A study of the amounts of nitrogen, phosphorus, and potassium removed by some of the common farm crops will show how rapidly these elements are used up under average farming conditions.

The amounts of these elements in various farm crops are given in table I. The amount of calcium and sulfur in the crops is not included as it is only recently that the removal of these elements has been considered important enough to warrant analyses.

The figures in the table show also the value of the three elements contained in the different crops, calculated from the market value of fertilizers containing them. Thus the value of nitrogen is figured at 16 cents per pound, the cost of the element in nitrate of soda; phosphorus at 12 cents, the cost of acid phosphate, and potassium at 6 cents, the cost in muriate of potash.

It is evident from the table that the continuous growing of any common farm crop without returning these three important elements will lead finally to a shortage of plant food in the soil. The nitrogen supply is drawn on the most heavily by all the crops, but in the case of alfalfa and clover only a small part should be taken from the soil. If these legumes are inoculated *as they should be*, they will take most of their nitrogen from the atmosphere. The figures are therefore entirely too high for the nitrogen taken from the soil by these two crops, but the loss of nitrogen from the soil by removal in nonleguminous crops is considerable. The phosphorus and potassium in the soil are also rapidly reduced by the growth of ordinary crops. While the nitrogen supply must be

TABLE I. PLANT FOOD IN CROPS AND VALUE

Circulating Nitrogen (N) at 16c (Sodium Nitrate ($NaNo_3$)), Phosphorus (P) at 12c (Acid Phosphate), and Potassium (K) at 6c (Potassium Chloride (KCl))

Crop	Yield	Plant Food, Lbs.			Value of Plant Food			Total Value of Plant Food
		Nitrogen	Phosphorus	Potass'm	Nitrog'n	Phosphorus	Potass'm	
Corn, grain	75 bu.	75	12.75	14	$12.00	$1.53	$0.84	$14.37
Corn, stover	2.25 T.	36	4.5	39	5.76	0.54	2.34	8.64
Corn, crop	......	111	17.25	53	17.76	2.07	3.18	23.01
Wheat, grain	30 bu.	42.6	7.2	7.8	6.81	0.86	0.46	8.13
Wheat, straw	1.5 T.	15	2.4	27	2.40	0.28	1.62	4.30
Wheat, crop	......	36.6	9.6	34.8	9.21	1.14	2.08	12.43
Oats, grain	50 bu.	33	5.5	8	5.28	0.66	0.48	6.42
Oats, straw	1.25 T.	15.5	2.5	26	2.48	0.30	1.56	8.28
Oats, crop	......	48.5	8	34	7.76	0.96	2.04	14.70
Barley, grain	30 bu.	23	5	5 5	3.68	0.60	0.33	4.61
Barley, straw	0.75 T.	9.5	1	13	1.52	0.12	0.78	2.42
Barley, crop	......	32.5	6	18.5	5.20	0.72	1.11	7.03
Rye, grain	30 bu.	29.4	6	7.8	4.70	0.72	0.46	5.88
Rye, straw	1.15 T.	12	3	21	1.92	0.36	1.26	3.54
Rye, crop	......	41.4	9	28.8	6.62	1.08	1.72	9.42
Potatoes	300 bu.	63	12.7	90	10.08	1.52	5.40	17.00
Alfalfa, hay	6 T.	300	27	144	48.00	3.24	8.64	59.88
Timothy hay	6 T.	72	9	67.5	11.52	1.08	1.95	16.55
Clover hay	3 T.	120	15	90	19.20	1.80	5.40	16.40

kept up by the use of leguminous green manure crops, phosphorus and potassium must be supplied by the use of expensive commercial fertilizers.

The cash value of the plant food removed from soils by the growth and sale of various crops is considerable. Even where the grain alone is sold and the crop residues are returned to the soil there is a large loss of fertility, and if the entire crop is removed and no return made, the loss is almost doubled. It is evident, therefore, that in calculating the actual income from the sale of farm crops, the value of the plant food removed from the soil should be subtracted from the proceeds, at least in the case of constituents which must be replaced at the present time.

Of course, if the crops produced are fed on the farm and the manure is carefully preserved and used, a large part of the valuable matter in the crops will be returned to the soil. This is the case in livestock and dairy farming where the products sold contain only a portion of the valuable elements of plant food removed from the soil. In grain farming, however, green manure crops and commercial fertilizers must be depended upon to supply plant food deficiencies in the soil. It should be mentioned that the proper use of crop residues in this latter system of farming reduces considerably plant food loss.

REMOVAL FROM IOWA SOILS

It has been conservatively estimated that the plant food taken from Iowa soils and shipped out of the state in grain amounts to about $30,000,000 annually. This calculation is based on the estimate of the secretary of the Western Grain Dealers' Association that 20 per cent of the corn and 35 to 40 per cent of the oats produced in the state is shipped off the farms.

This loss of fertility is unevenly distributed over the state, varying as farmers do more or less livestock and dairy farming or grain farming. In grain farming, where no manure is produced and the entire grain crop is sold, the soil may very quickly become deficient in certain necessary plant foods. Eventually, however, all soils are depleted in essential food materials, whatever system of farming is followed.

The loss of fertility is great enough to demand serious attention. Careful consideration should certainly be given to all means of maintaining the soils of the state in a permanently fertile condition.

PERMANENT FERTILITY IN IOWA SOILS

The preliminary study of Iowa soils, already reported,* revealed the fact that there is not an inexhaustible supply of nitrogen, phosphorus and potassium in the soils of the state. Potassium was found in much larger amounts than the other two elements, and it was concluded, therefore, that attention should be centered at the present time on nitrogen and phosphorus. In spite of the fact that Iowa soils are still comparatively fertile and crops are still large, there is abundant evidence at hand to prove that the best possible yields of certain crops are not being obtained in many cases because of the lack of necessary plant foods or because of the lack of proper conditions in the soil for the prowth of plants and the production, by bacteria, of available plant food.

Proper systems of farming will insure the production of satisfactory crops and the maintenance of permanent fertility and the adoption of such systems should not be delayed until crop yields are much lower, for then it will involve a long, tedious and very expensive fight to bring the soil back to a fertile condition. If proper methods are put into operation while comparatively large amounts of certain plant foods are still present in the soil, it is relatively easy to keep them abundant and attention may be centered on those other elements likely to be limiting factors in crop production.

Soils may be kept permanently fertile by adopting certain practices which will be summarized here.

CULTIVATION AND DRAINAGE

Cultivation and drainage are two of the most important farm operations in keeping the soil in a favorable condition for crop production, largely because they help to control the moisture in the soil.

The moisture in soils is one of the most important factors governing crop production. If the soil is too dry, plants suffer for a lack of the water necessary to bring them their food and also for a lack of available plant food. Bacterial activities are so restricted in dry soils that the production of available food practically ceases. If too much moisture is present, plants likewise refuse to grow properly because of the exclusion of air from the soil and the absence of available food. Decay is checked in the absence of air, all beneficial bacterial action is limited and humus, or organic matter, containing plant food constituents in an unavailable form, accumulates. The infertility of low-lying, swampy soils is a good illustration of the action of excessive moisture in restricting plant growth by stopping aeration and limiting beneficial decay processes.

While the amount of moisture in the soil depends very largely on the rainfall, any excess of water may be removed from the soil by drainage and the amount of water present in the soil may be conserved during periods of drought by thoro cultivation or the maintaining of a good mulch. The need for drainage is determined partly by the nature of the soil, but more particularly by the subsoil. If the subsoil is a heavy, tight clay, a surface clay loam will be rather readily affected by excessive rainfall. On the other hand, if the surface soil is sandy, a heavy subsoil will be of advantage in preventing the rapid drying out of the soil and also in checking losses of valuable matter by leaching.

Many acres of land in the Wisconsin drift area in Iowa have been reclaimed and made fertile thru proper drainage, and one of the most important farming operations is the laying of drains to insure the removal of excessive moisture in heavy soils.

The loss of moisture by evaporation from soils during periods of drought may be checked to a considerable extent if the soil is cultivated and a good mulch is maintained. Many pounds of valuable water are thus held in the soil and a satisfactory crop growth secured when otherwise a failure would occur. Other methods of soil treatment, such as liming, green manuring and the application of farm manures, are also important in increasing the water-holding power of light soils.

THE ROTATION OF CROPS

Experience has shown many times that the continuous growth of one crop takes the fertility out of a soil much more rapidly than a rotation of crops. One of the most important farm practices, therefore, from the standpoint of soil fertility, is the rotation of crops on a basis suited to the soil, climatic, farm and market conditions. The choice of crops is so large that no difficulty should be experienced in selecting those suitable for all conditions.

*Bulletin 150, Iowa Agricultural Experiment Station.

Probably the chief reason why the rotation of crops is beneficial may be found in the fact that different crops require different amounts of the various plant foods in the soil. One particular crop will remove a large amount of one element and the next crop, if it be the same kind, will suffer for a lack of that element. If some other crop, which does not draw as heavily on that particular plant food, is rotated with the former crop, a balance in available plant food is reached.

Where a cultivated crop is grown continuously, there is a much greater loss of organic matter or humus in the soil than under a rotation. This fact suggests a second explanation for the beneficial effects of crop rotations. With cultivation, bacterial action is much increased and the humus in the soil may be decomposed too rapidly and the soil injured by the removal of the valuable material. Then the production of available plant food in the soil will be hindered or stopped and crops may suffer. The use of legumes in rotations is of particular value since when they are well inoculated and turned under they not only supply organic matter to the soil, but they also increase the nitrogen content.

There is a third explanation of the value of rotations. It is claimed that crops in their growth produce certain substances called "toxic" which are injurious to the same crop, but have no effect on certain other crops. In a proper rotation the time between two different crops of the same plant is long enough to allow the "toxic" substance to be disposed of in the soil or made harmless. This theory has not been commonly accepted, chiefly because of the lack of confirmatory evidence. It seems extremely doubtful if the amounts of these "toxic" substances could be large enough to bring about the effects evidenced in continuous cropping.

But, whatever the reason for the bad effects of continuous cropping, it is evident that for all good systems of farming some definite rotation should be adopted, and that rotations should always contain a legume, because of the value of such crops to the soil. In no other way can the humus and nitrogen content of soils be kept up so cheaply and satisfactorily as by the use of legumes, either as regular or "catch" crops in the rotation.

MANURING

There must always be enough humus, or organic matter, and nitrogen in the soil if satisfactory crops are to be secured. Humus not only keeps the soil in the best physical condition for crop growth, but it supplies a considerable portion of nitrogen. An abundance of humus may always be considered a reliable indication of the presence of much nitrogen. This nitrogen does not occur in a form available for plants, but with proper physical conditions in the soil, the nonusable nitrogen in the animal and vegetable matter which makes up the humus, is made usable by numerous bacteria and changed into soluble and available nitrates.

The humus, or organic matter, also encourages the activities of many other bacteria which produce carbon dioxide and various acids which dissolve and make available the insoluble phosphorus and potassium in the soil.

Three materials may be used to supply the organic matter and nitrogen of soils. These are farm manure, crop residues and green manure, the first two being much more common.

Farm manure is composed of the solid and liquid excreta of animals, litter, unconsumed food and other waste materials, and supplies an abundance of organic matter, much nitrogen and millions of valuable bacteria. It contains, in short, a portion of the plant food present in the crops originally removed from the soil and in addition the bacteria necessary to prepare this food for plant use. If it were possible to apply large enough amounts of farm manure, no other material would be necessary to keep the soil in the best physical condition, insure efficient bacterial action and keep up the plant food supply. But manure cannot serve the soil thus efficiently, for even under the very best methods of treatment and storage, 15 per cent of its valuable constituents, mainly nitrogen, are lost. Furthermore, only in a very few instances is enough produced on a farm to supply its needs. On practically all soils, therefore, some other material must be applied with the manure to maintain fertility.

Crop residues, consisting of straw, stover, roots and stubble, are important in keeping up the humus, or organic matter content of soils. Table I shows that a considerable portion of the plant food removed by crops is contained in the straw and stover. On all farms, therefore, and especially on grain farms, the crop residues should be returned to the soil to reduce the losses of plant food and also to aid in maintaining the humus content. These materials alone are, of course, insufficient and farm manure must be used when possible, and green manures also.

Green manuring should be followed to supplement the use of farm manures and crop residues. In grain farming, where little or no manure is produced, the turning under of leguminous crops for green manures must be relied upon as the best means of adding humus and nitrogen to the soil, but in all other systems of farming also it has an important place. A large number of legumes will serve as green manure crops and it is possible to introduce some such crop into almost any rotation without interfering with the regular crop. It is this peculiarity of legumes, together with their ability to use the nitrogen of the atmosphere when well inoculated, and thus increase the nitrogen content of the soil, which gives them their great value as green manure crops.

It is essential that the legumes used be well inoculated. Their ability to use the atmospheric nitrogen depends on that. Inoculation may be accomplished by the use of soil from a field where the legume has previously been successfully grown and well inoculated, or by the use of inoculating material that may be purchased. If the legume has never been grown on the soil before, or has been grown without inoculation, then inoculation should be practiced by one of these methods.

By using all the crop residues, all the manure produced on the farm, and giving well-inoculated legumes a place in the rotation for green manure crops, no artificial means of maintaining the humus and nitrogen content of soils need be resorted to.

THE USE OF PHOSPHORUS

Iowa soils are not abundantly supplied with phosphorus. Moreover, it is impossible by the use of manures, green manures, crop residues, straw, stover, etc., to return to the soil the entire amount of that element removed by crops. Crop residues, stover and straw merely return a portion of the phosphorus removed, and while their use is important in checking the loss of the element, they cannot stop it. Green manuring adds no phosphorus that was not used in the growth of the green manure crop. Farm manure returns part of the phosphorus removed by crops which are fed on the farm, but not all of it. While, therefore, immediate scarcity of phosphorus in Iowa soils cannot be positively shown, analyses and results of experiments show that in the more or less distant future, phosphorus must be applied or crops will suffer for a lack of this element. Furthermore, there are indications that its use at present would prove profitable in some instances.

Phosphorus may be applied to soils in three commercial forms, bone meal, acid phosphate and rock phosphate. Bone meal cannot be used generally, because of its extremely limited production, so the choice rests between rock phosphate and acid phosphate. Experiments are now under way to show which is more economical for all farmers in the state. Many tests must be conducted on a large variety of soil types, under widely differing conditions, and thru a rather long period of years. It is at present impossible to make these experiments as complete as desirable, owing to small appropriations for such work, but the results secured from the tests now in progress will be published from time to time in the different county reports.

Until such definite advice can be given for individual soil types, it is urged that farmers who are interested make comparisons of rock phosphate and acid phosphate on their own farms. In this way they can determine at first hand the relative value of the two materials. Information and suggestions regarding the carrying out of such tests may be secured upon application to the Soils Section.

LIMING

Practically all crops grow better on a soil which contains lime, or in other words, on one which is not acid. As soils become acid, crops grow smaller, bacterial activities are reduced and the soil becomes infertile. Crops are differently affected by acidity in the soil; some refuse to grow at all; others grow but poorly. Only in a very few instances can a satisfactory crop be secured in the absence of lime. Therefore, the addition of lime to soils in which it is lacking is an important principle in permanent soil fertility. All soils gradually become acid because of the losses of lime and other basic materials thru leaching and the production of acids in the decomposition processes constantly occurring in soils. Iowa soils are no exception to the general rule, as was shown by the tests of many representative soils reported in bulletin No. 151 of this Station. Particularly are the soils in the Iowan drift, Mississippi loess and Southern Iowa loess areas likely to be acid.

All Iowa soils should therefore be tested for acidity before the crop is seeded, particularly when legumes, such as alfalfa or red clover, are to be grown. Any farmer may test his own soil and determine its need of lime, according to simple directions in bulletin 151, referred to above.

SOIL AREAS IN IOWA

There are five large soil areas in Iowa, the Wisconsin drift, the Iowan drift, the Missouri loess, the Mississippi loess and the Southern Iowa loess. These five divisions of the soils of the state are based on the geological forces which brought about the formation of the various soil areas. The various areas are shown in the map, fig. 11.

With the exception of the northeastern part of the state, the whole surface of Iowa was in ages past overrun by great continental ice sheets. These great masses of ice moved slowly over the land, crushing and grinding the rocks beneath and carrying along with them the material which they accumulated in their progress. Five ice sheets invaded Iowa at different geological eras, coming from different directions and carrying, therefore, different rock material with them.

The deposit, or sheet, of earth debris left after the ice of such glaciers melts is called "glacial till" or "drift" and is easily distinguished by the fact that it is usually a rather stiff clay containing pebbles of all sorts as well as large boulders or "nigger-heads." Two of these drift areas occur in Iowa today, the Wisconsin drift and the Iowan drift, covering the north central part of the state. The soils of these two drift areas are quite different in chemical composition, due primarily to the different ages of the two ice invasions. The Iowan drift soil was laid down at a much earlier period and is somewhat poorer in plant food than the Wisconsin drift soil, having undergone considerable leaching in the time which has elapsed since its formation.

The drift deposits in the remainder of the state have been covered by so-called loess soils, vast accumulations of dust-like materials which settled out of the air during a period of geological time when climatic conditions were very different than at present. These loess soils are very porous in spite of their fine texture and they rarely contain large pebbles or stones. They present a strong contrast to the drift soils, which are somewhat heavy in texture and filled with pebbles and stones. The three loess areas in the state, the Missouri, the Mississippi and the Southern Iowa, are distinguished by differences in texture and appearance, and they vary considerably in value for farming purposes. In some sections the loess is very deep, while in other places the underlying leached till or drift soil is very close to the surface. The fertility of these soils and their needs are greatly influenced, therefore, by their depth.

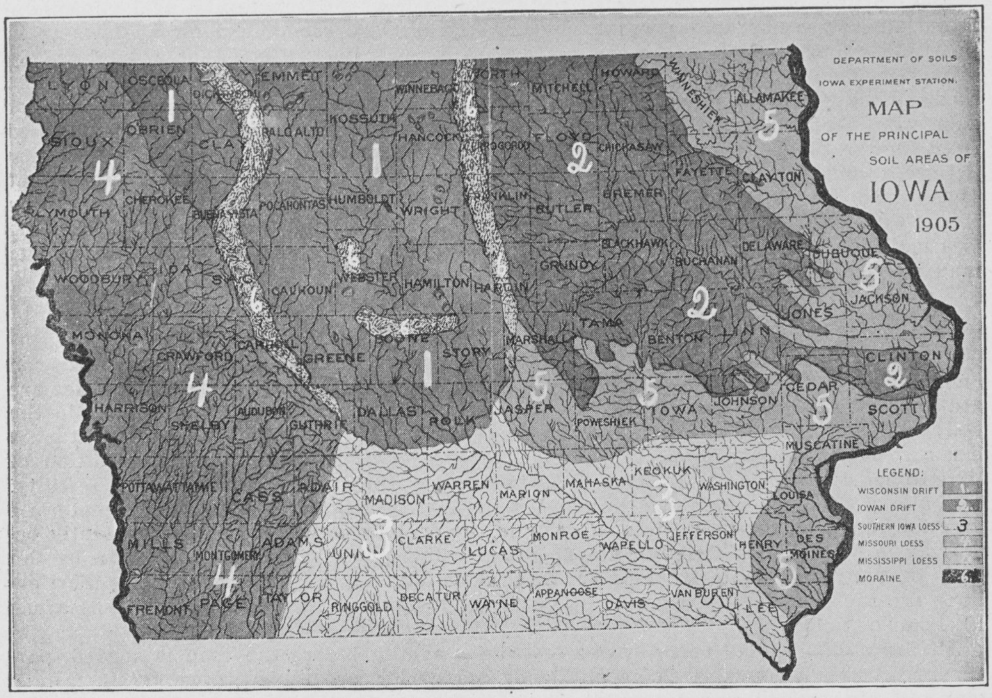


Fig. 11. Map showing the principal soil areas in Iowa

It will be seen that the soils of the state may be roughly divided into two classes, drift soils and loess soils, and that further divisions may then be made into various drift and loess soils because of differences in period of formation, characteristics and general composition. More accurate information demands, however, that further divisions be made. The different drift and loess soils contain large numbers of soil types which vary among themselves, and each of these should receive special attention.

THE SOIL SURVEY BY COUNTIES

It is apparent that a general survey of the soils of the state can give only a very general idea of soil conditions. Soils vary so widely in character and composition, depending on many other factors than their source, that definite knowledge concerning their needs can be secured only by thoro and complete study of them in place in small areas. Climatic conditions, topography, depth and character of soil, chemical and mechanical composition and all other factors affecting crop production must be considered.

This is what is accomplished by the soil survey of the state by counties, and hence the needs of individual soils, and proper systems of management may be worked out in much greater detail and be much more complete than would be possible by merely considering the large soil areas separated on the basis of their geological origin. In other words, while the unit in the general survey is the geological history of the soil area, in the soil survey by counties or any other small area, the unit is the soil type.

GENERAL SOIL CHARACTERISTICS

Soil types possess more or less definite characteristics which may be determined largely in the field, altho some laboratory study is necessary for final disposition. Usually the line of separation between adjoining soil types is quite distinct and it is a simple matter to locate the type boundaries. In some cases, however, there is a gradation from one type to another and then the boundaries may be fixed only with great difficulty. The error introduced into the soil survey work from this source is very small and need cause little concern.

The factors which must be taken into account in establishing soil types have been well enumerated by the Illinois Agricultural Experiment Station in its Soil Report No. 1:

1. The geological origin of the soil, whether residual, glacial, loessial, alluvial, colluvial or cumulose.
2. The topography or lay of the land.
3. The structure or depth and character of the surface, subsurface and subsoil.
4. The physical or mechanical composition of different strata composing the soil, as the percentages of gravel, sand, silt, clay and organic matter which they contain.
5. The texture or porosity, granulation, friability, plasticity, etc.
6. The color of the strata.
7. The natural drainage.
8. The natural drainage.
8. The agricultural value based upon its natural productiveness.
9. Native vegetation.
10. The ultimate chemical composition and reaction.

The common soil constituents may be given as follows:†

Organic Matter { All partially destroyed or undecomposed vegetable and animal material.

Inorganic Matter {
- Stones—over 32 mm.*
- Gravel—32—2.0 mm.
- Very coarse sand—2.0—1.0 mm.
- Coarse sand—1.0—0.5 mm.
- Medium sand—0.5—0.25 mm.
- Fine Sand—0.25—0.10 mm.
- Very fine Sand—0.10—0.05 mm.
- Silt—0.05—0.00 mm.

SOILS GROUPED BY TYPES

The general groups of soils by types are indicated thus by the Bureau of Soils:‡

Peats—Consisting of 35 per cent or more of organic matter, sometimes mixed with more or less sand or soil.

*25 mm. equals 1 in. † Bur. of Soils Field Book. ‡Loc. cit.

Peaty Loams—15 to 35 per cent of organic matter mixed with much sand and silt and a little clay.

Mucks—25 to 35 per cent of partly decomposed organic matter mixed with much clay and some silt.

Clays—Soils with more than 30 per cent clay, usually mixed with much silt; always more than 50 per cent silt and clay.

Silty Clay Loams—20 to 30 per cent clay and more than 50 per cent silt.

Clay Loams—20 to 30 per cent clay and less than 50 per cent silt and some sand.

Silt Loams—20 per cent clay and more than 50 per cent silt mixed with some sand.

Loams—Less than 20 per cent clay and less than 50 per cent silt and from 30 to 50 per cent sand.

Sandy Clays—20 per cent silt and small amounts of clay up to 30 per cent.

Fine Sandy Loams—Fore than 50 per cent fine sand and very fine sand mixed with less than 25 per cent very coarse sand, coarse sand and medium sand, much silt and a little clay; silt and clay 20 to 50 per cent.

Sandy Loams—More than 25 per cent very coarse, coarse and medium sand; silt and clay 20 to 50 per cent.

Very Fine Sand—More than 50 per cent fine sand and less than 25 per cent very coarse, coarse and medium sand, less than 20 per cent silt and clay.

Fine Sand—More than 50 per cent fine sand and less than 25 per cent very coarse, coarse and medium sand, less than 20 per cent silt and clay.

Sand—More than 25 per cent very coarse, coarse and medium sand, less than 50 per cent find sand, less than 20 per cent silt and clay.

Coarse Sand—More than 25 per cent very coarse, coarse and medium sand, less than 50 per cent of other grades, less than 20 per cent silt and clay.

Gravelly Loams—25 to 50 per cent very coarse sand and much sand and some silt.

Gravels—More than 50 per cent very coarse sand.

Stony Loams—A large number of stones over one inch in diameter.

METHODS USED IN THE SOIL SURVEY

It may be of some interest to state briefly the methods which are followed in the field in surveying soils.

As has been indicated, the completed map is intended to show the accurate location and boundaries, not only of all the soil types but also of the streams, roads, railroads, etc.

The first step, therefore, is the choice of an accurate base map and any official map of the county may be chosen for this purpose. Such maps are always checked to correspond correctly with the land survey. The location of every stream, road and railroad on the map is likewise carefully verified and corrections are frequently necessary. When an accurate base map is not available the field party must first prepare one.

The section is the unit area by which each county is surveyed and mapped. The distances in the roads are determined by an odometer attached to the vehicle, and in the field by pacing, which is done with accuracy. The directions of the streams, roads, railroads, etc., are determined by the use of the compass and the plane table. The character of the soil types is ascertained in the section by the use of the auger, an instrument for sampling both the surface soil and the subsoil. The boundaries of each type are then ascertained accurately in the section and indicated on the map. Many samplings are frequently necessary, and individual sections may contain several soil types and require much time for mapping. In other cases, the entire section may contain only one type, which fact is readily ascertained, and in that case the mapping may proceed rapidly.

When one section is completed, the party passes to the next section and the location of all soil types, streams, etc., in that section is then checked with their location in the adjoining area just mapped. Careful attention is paid to the topographical features of the area, or the "lay of the land," for the character of the soils is found to correspond very closely to the conditions under which they occur.

The field party is composed of two men, and all observations, measurements and soil type boundaries are compared and checked by each man.

The determinations of soil type are verified also by inspection by and consultation with those in charge of the work at the Bureau of Soils and at the Iowa Agricultural Experiment Station. When the entire county is completed, all the section maps or field sheets are assembled and any variations or questionable boundaries are verified by further observations of the particular area.

The completed may, therefore, shows as accurately as possible all soils and soil boundaries, and it constitutes also an exact road map of the county.